NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

CATALOGUE FOR 1972-1974

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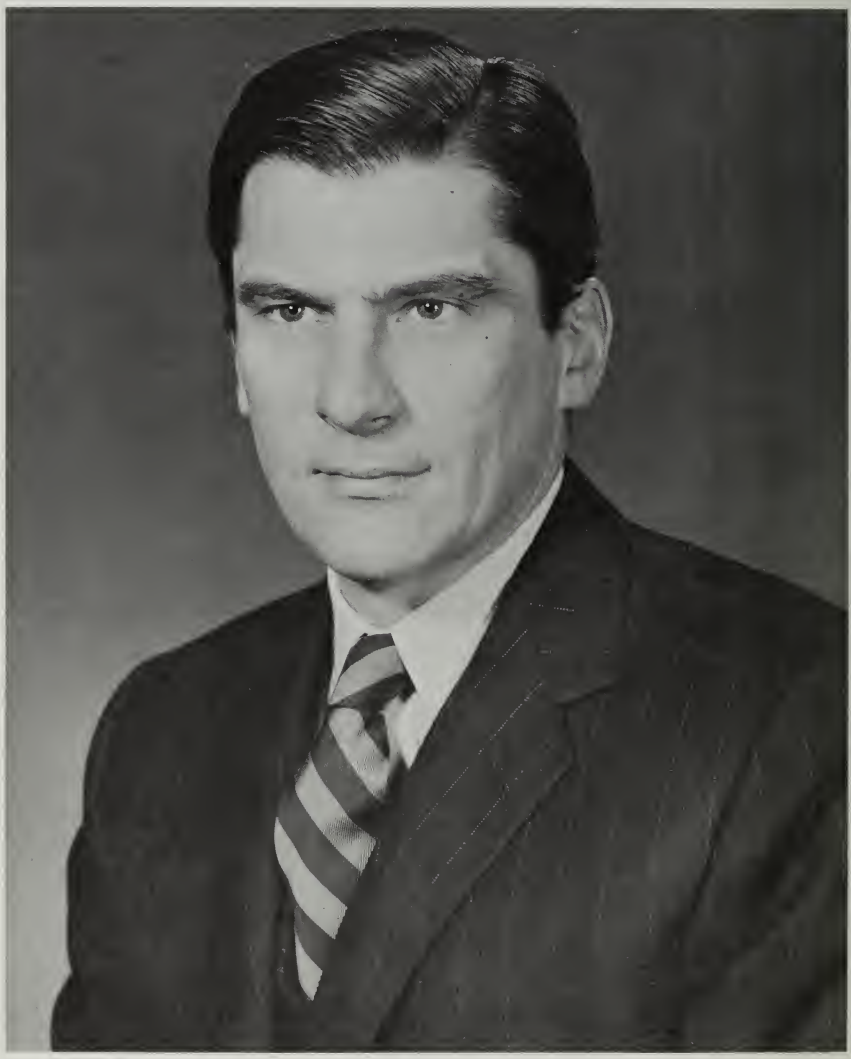

The Honorable
JOHN W. WARNER
Secretary of the Navy

POLICY

The Secretary of the Navy has stated the following policy on graduate education for U. S. Navy and U. S. Marine Corps officers:

"Raise the educational base of our officers.

"Increase by undergraduate full-time study or by off-duty study, the numbers of officers qualified for graduate education.

"Encourage voluntary application for graduate education.

"Order to advanced education as many qualified officers as possible to meet the Navy's and Marine Corps' requirements for graduate education.

"Utilize the graduate education of individuals whether obtained in off-duty study, in tuition aid programs, in government fully-funded programs, or however obtained, giving due attention to the broad professional experience which supplements the officer's educational background.

"Insure that performance in all duty assignments is the primary criterion for promotion. Emphasize to all officers that graduate education coupled with outstanding performance will enhance an officer's chances for promotion. Selection boards must recognize this as a potent factor in judging the career performance of officers considered for promotion."

MISSION

The Secretary of the Navy has defined the mission of the Naval Postgraduate School as follows:

"To conduct and direct the Advanced Education of commissioned officers, and to provide such other technical and professional instruction as may be prescribed to meet the needs of the Naval Service; and in support of the foregoing, to foster and encourage a program of research in order to sustain academic excellence."

Superintendent

MASON BEHR FREEMAN
B. S., U. S. Naval Academy, 1935
Naval Postgraduate School, 1943
National War College, 1957

Academic Dean

MILTON URE CLAUSER

B. S., California Institute of Technology, 1934;
M. S., 1935; Ph. D., 1937

BOARD OF ADVISORS

The NPS Board of Advisors is a distinguished group of civilian educators, business and professional men. The Board visits the campus periodically to examine educational programs, recommend improvements and discuss plans and problems with the Superintendent. Present members are:

Dr. Ralph D. Bennett, Independent Consultant

Rear Admiral William A. Brockett, USN, Ret., President, Webb Institute of Naval Architecture

Dr. Lawrence R. Hafstad (Board Chairman), Chairman, Committee on Undersea Warfare of the National Research Council

Mr. Richard R. Hough, Vice President, American Telephone and Telegraph Co.

Dr. Neil H. Jacoby, Dean, University of California at Los Angeles, Graduate School of Business Administration

Admiral I. C. Kidd, Chief of Naval Material, Navy Department (nominated)

Dr. George J. Maslach, Dean, College of Engineering, University of California at Berkeley

Dr. Dean E. McHenry, Chancellor, University of California at Santa Cruz

Dr. David S. Potter, Chief Engineer, Milwaukee Operations, Delco Electronics, General Motors Corporation

Admiral James S. Russell, USN, Ret., Consultant, Boeing Aircraft

Mr. Emmett G. Solomon, Chairman of the Board, Crocker National Bank

NAVAL POSTGRADUATE SCHOOL

Chief of Staff

JOHN EDWARD MCQUARY
Captain, U. S. Navy
A. B., University of California at Berkeley, 1942

Director of Programs

DONALD WALTER KILEY
Captain, U. S. Navy
B. S., Naval Postgraduate School, 1954
Aeronautical Engineer, California Institute of Technology, 1955

Director of Military Operations and Logistics

EDWARD EVERETT RILEY
Captain, U. S. Navy
B. S., U. S. Naval Academy, 1946
M. A. in Economics, American University, 1961

Dean of Programs

WILBERT FREDERICK KOEHLER
B. S., Allegheny College, 1933; M. A.,
Cornell University, 1934; Ph. D., Johns Hopkins University, 1948

Deputy Director of Programs

Dean of Curricula

BROOKS JAVINS LOCKHART
B. A., Marshall University, 1937; M. S., West
Virginia University, 1940; Ph. D., University of Illinois, 1943

Dean of Research Administration

JOHN MCREYNOLDS WOZENCRAFT
B. S., U. S. Military Academy, 1946
M. S., Massachusetts Institute of
Technology, 1951; E. E., 1951; Ph. D., 1957

Registrar

MISS EDITH JEAN WARRINER
B. A., Occidental College, 1947

SUPERINTENDENT'S STAFF ASSISTANTS

Aide to the Superintendent ..... LTJG James George Harwood, USNR
Comptroller ..... CAPT Jerome Joseph Scheela, SC, USN
Civilian Personnel Officer ..... Mr. Weston Burton Lockwood

PROGRAMS ADMINISTRATIVE STAFF

Plans Officer ..... CDR David Neil Orrik, USN
Flight Officer ..... CDR Donald Thomas Fitzgerald, USN
Administrative Officer ..... CDR Phyllis Louanna Schultz, USN
Academic Assistant ..... LT Susan Ruth Hanauer, USN
Foreign Training Officer ..... LCDR Donald Arthur Spaugy, USN
Marine Corps Representative ..... LTCOL John Henry Smith, USMC
Submarine Liaison Officer ..... LCDR Philip John O'Connell, Jr., USN

MILITARY OPERATIONS AND LOGISTICS STAFF

Director, Administration Dept. ..... CDR Kenneth Ashley Hamman, USN
Director, Supply Dept. ..... CDR Graydon Mann Durham, Jr., SC, USN
Director, Public Works Dept. ..... CDR Ralph Michael Cerreta, CEC, USN
Director, Medical Department ..... CAPT Ronald Aloysius Cummings, MC, USN
Director, Dental Dept. ..... CAPT James Francis Keenan, DC, USN
Deputy Director of Military Operations and Logistics ..... CDR Ernest Fischbein, USN
Catholic Chaplain ..... CAPT Joseph Emmet Ryan, CHC, USN
Protestant Chaplain ..... CAPT William Roy Samuel, CHC, USN
Legal Officer ..... LT James Sidney Conner, Jr., JAGC, USNR
Communications Officer ..... LT Katheleen Hansen, USN
First Lieutenant ..... LCDR Eugene Marquis Toscano, USN
Public Affairs Officer ..... LT John Francis McGuire, USN

CALENDAR FOR 1972-73 ACADEMIC YEAR

1972

Registration for BS/BA, IGEP, Management Curricula	Monday, 26 June
Quarter I Begins (1972-73)	Monday, 3 July
Fourth of July (holiday)	Tuesday, 4 July
Language Examination in French, German, Russian for Ph. D. Candidates	Monday, 7 August
Refresher Course Begins	Monday, 14 August
Labor Day (holiday)	Monday, 4 September
Final Date for Completion of Thesis for September Graduation	Tuesday, 12 September
Registration for all Curricula except BS/BA, Management	Monday, 18 September
Examination Week for Quarter I	18-22 September
Quarter I Ends	Friday, 22 September
Graduation	Friday, 22 September
Quarter II Begins	Monday, 25 September
Columbus Day (holiday)	Monday, 9 October
Language Examination in French, German, Russian for Ph. D. Candidates	Monday, 16 October
Veterans Day (holiday)	Monday, 23 October
Refresher Course Begins	Monday 20 November
Thanksgiving Day (holiday)	Thursday, 23 November
Final Date for Completion of Thesis for December Graduation	Tuesday, 5 December
Examination Week for Quarter II	11-15 December
Quarter II Ends	Friday, 15 December
Graduation	Friday, 15 December
Christmas (holiday)	Monday, 25 December
Registration for BS/BA, IGEP, Management Curricula	Wednesday, 27 December

1973

New Years Day (holiday)	Monday, 1 January
Quarter III Begins	Tuesday, 2 January
Language Examination in French, German, Russian for Ph. D. Candidates	Monday, 15 January
Refresher Course Begins	Monday, 12 February
Washington's Birthday (holiday)	Monday, 19 February
Final Date for Completion of Thesis for March Graduation	Tuesday, 13 March
Registration for all Curricula except BS/BA, Management	Monday, 19 March
Examination Week for Quarter III	19-23 March
Quarter III Ends	Friday, 23 March
Graduation	Friday, 23 March
Quarter IV Begins	Monday, 26 March
Language Examination in French, German, Russian, for Ph. D. Candidates	Monday, 16 April
Refresher Course Begins	Monday, 21 May
Memorial Day (holiday)	Monday, 28 May
Final Date for Completion of Thesis for June Graduation	Tuesday, 5 June
Examination Week for Quarter IV	11-15 June
Quarter IV Ends (1972-73)	Friday, 15 June
Graduation	Friday, 15 June

CALENDAR FOR 1973-74 ACADEMIC YEAR

1973

Registration for BS/BA, IGEP, Management Curricula	Monday, 25 June
Quarter I Begins (1973-74)	Monday, 2 July
Fourth of July (holiday)	Wednesday, 4 July
Language Examination in French, German, Russian for Ph. D. Candidates	Monday, 6 August
Refresher Course Begins	Monday, 13 August
Labor Day (holiday)	Monday, 3 September
Final Date for Completion of Thesis for September Graduation	Tuesday, 11 September
Registration for all Curricula except BS/BA, Management	Monday, 17 September
Examination Week for Quarter I	17-21 September
Quarter I Ends	Friday, 21 September
Graduation	Friday, 21 September
Quarter II Begins	Monday, 24 September
Columbus Day (holiday)	Monday, 8 October
Language Examination in French, German, Russian for Ph. D. Candidates	Monday, 15 October
Veterans Day (holiday)	Monday, 22 October
Thanksgiving Day (holiday)	Thursday, 22 November
Refresher Course Begins	Monday, 26 November
Final Date for Completion of Thesis for December Graduation	Tuesday, 4 December
Examination Week for Quarter II	10-14 December
Quarter II Ends	Friday, 14 December
Graduation	Friday, 14 December
Christmas (holiday)	Tuesday, 25 December
Registration for BS/BA, IGEP, Management Curricula	Monday, 31 December

1974

1974

New Years Day (holiday)	Tuesday, 1 January
Quarter III Begins	Monday, 7 January
Language Examination in French, German, Russian for Ph. D. Candidates	Monday, 21 January
Washington's Birthday (holiday)	Monday, 18 February
Refresher Course Begins	Tuesday, 19 February
Final Date for Completion of Thesis for March Graduation	Tuesday, 19 March
Registration for all Curricula except BS/BA, Management	Monday, 25 March
Examination Week for Quarter III	25-29 March
Quarter III Ends	Friday 29 March
Graduation	Friday, 29 March
Quarter IV Begins	Monday, 1 April
Language Examination in French, German, Russian for Ph. D. Candidates	Monday, 15 April
Memorial Day (holiday)	Monday, 27 May
Refresher Course Begins	Tuesday, 28 May
Final Date for Completion of Thesis for June Graduation	Tuesday, 11 June
Examination Week for Quarter IV	17-21 June
Quarter IV Ends (1973-74)	Friday, 21 June
Graduation	Friday, 21 June
Registration for BS/BA, IGEP, Management Curricula	Monday, 1 July
Fourth of July (holiday)	Thursday, 4 July
Quarter I Begins (1974-75)	Monday, 8 July
Language Examination in French, German, Russian, for Ph. D. Candidates	Monday, 12 August
Refresher Course Begins	Monday, 19 August
Labor Day (holiday)	Monday, 2 September
Final Date for Completion of Thesis for September Graduation	Tuesday, 17 September
Registration for all Curricula except BS/BA, Management	Monday, 23 September
Examination Week for Quarter I	23-27 September
Quarter I Ends	Friday, 27 September
Graduation	Friday, 27 September
Quarter II Begins	Monday, 30 September

DISTINGUISHED ALUMNI

Among those who have completed a Naval Postgraduate School curriculum who attained flag (USN) or general (USMC) rank on the active list are the following: (The asterisk (*) indicates those on active list as of 1 January 1972).

Admiral Walter F. Boone
Admiral Arleigh A. Burke
General Clifton B. Cates
Admiral Maurice E. Curts
Admiral Robert L. Dennison
Admiral Donald B. Duncan
Admiral Cato D. Glover, Jr.
Admiral Roscoe F. Good
Admiral Charles D. Griffin
Admiral Byron H. Hanlon
Admiral Ephraim P. Holmes
Admiral Royal E. Ingersoll
Admiral Albert G. Noble
Admiral Alfred M. Pride
Admiral James O. Richardson
Admiral Horacio Rivero, Jr.*
Admiral Samuel M. Robinson
Admiral James S. Russell
Admiral Ulysses S. G. Sharp, Jr.
Admiral Felix B. Stump
General Merrill B. Twining
Admiral Alfred G. Ward
Admiral John M. Will
Vice Admiral Walter S. Anderson
Vice Admiral Harold D. Baker
Vice Admiral Wallace M. Beakley
Vice Admiral George F. Beardsley
Vice Admiral Frank E. Beatty
Vice Admiral Fred G. Bennett*
Vice Admiral Arthur Beshany*
Vice Admiral Robert E. Blick, Jr.
Vice Admiral Charles T. Booth, II
Vice Admiral Harold G. Bowen, Jr.*
Vice Admiral Carleton F. Bryant
Vice Admiral William M. Callaghan
Vice Admiral John H. Carson
Vice Admiral John L. Chew
Vice Admiral Ralph W. Christie
Vice Admiral Oswald S. Colclough
Vice Admiral John B. Colwell
Vice Admiral Thomas F. Connolly
Vice Admiral John C. Daniel
Vice Admiral Glenn B. Davis
Vice Admiral Vincent P. dePoix*
Vice Admiral Harold T. Deutermann
Vice Admiral Glynn R. Donaho
Vice Admiral James H. Doyle
Vice Admiral Irving T. Duke
Vice Admiral Ralph Earle, Jr.
Vice Admiral Clarence E. Ekstrom
Vice Admiral Emmet P. Forrestel
Vice Admiral William E. Gentner, Jr.
Vice Admiral Elton W. Grenfell
Vice Admiral Robert W. Hayler
Lieutenent General Geo. D. Hermle
Vice Admiral Ira E. Hobbs
Vice Admiral Edwin B. Hooper*
Vice Admiral George F. Hussey, Jr.
Vice Admiral Olaf M. Hustvedt
Vice Admiral Thomas B. Inglis
Vice Admiral Andrew M. Jackson, Jr.
Vice Admiral Albert E. Jarrell
Vice Admiral Tarry B. Jarrett
Lieutenant General Clayton C. Jerome
Vice Admiral Means Johnston, Jr.*
Vice Admiral Robert T. S. Keith
Vice Admiral Ingolf N. Kiland
Vice Admiral Jerome H. King, Jr.*
Vice Admiral Fred P. Kirtland
Vice Admiral Harold O. Larson
Vice Admiral Ruthven E. Libby
Vice Admiral Vernon L. Lowrance
Vice Admiral William J. Marshall
Vice Admiral Charles B. Martell
Vice Admiral Kleber S. Masterson
Vice Admiral John L. McCrea
Vice Admiral Ralph E. McShane
Vice Admiral Charles L. Melson
Vice Admiral Frederick H. Michaelis*
Vice Admiral Arthur C. Miles
Vice Admiral Gerald E. Miller*
Vice Admiral Marion E. Murphy
Vice Admiral Lloyd M. Mustin
Vice Admiral Frank O'Beirne
Vice Admiral Francis P. Old
Vice Admiral Howard E. Orem
Vice Admiral Harvey E. Overesch
Vice Admiral Edward N. Parker
Vice Admiral Raymond E. Peet*
Vice Admiral Charles A. Pownall
Vice Admiral Thomas C. Ragan
Vice Admiral Lawson P. Ramage
Vice Admiral William L. Rees
Vice Admiral Robert H. Rice
Vice Admiral Hyman G. Rickover*
Vice Admiral Rufus E. Rose
Vice Admiral Richard W. Ruble
Vice Admiral Theodore D. Ruddock, Jr.
Vice Admiral Lorenzo S. Sabin, Jr.
Vice Admiral Harry Sanders
Vice Admiral Walter G. Schindler
Vice Admiral William A. Schoech
Vice Admiral Harry E. Sears
Vice Admiral Thomas G. W. Settle
Vice Admiral William B. Smedberg, III
Vice Admiral Allan E. Smith
Vice Admiral Chester C. Smith
Vice Admiral John V. Smith*
Vice Admiral Roland N. Smoot
Lieutenant General Edward W. Snedeker
Vice Admiral Selden B. Spangler
Vice Admiral Thomas M. Stokes
Vice Admiral Paul D. Stroop
Vice Admiral John Sylvester
Vice Admiral Robert L. Townsend*
Vice Admiral Aurelius B. Voseller
Vice Admiral Thomas J. Walker, III*
Vice Admiral Homer N. Wallin
Vice Admiral Charles E. Weakley
Vice Admiral Charles Wellborn, Jr.
Vice Admiral George L. Weyler
Vice Admiral Ralph Weymouth*
Vice Admiral Charles W. Wilkins
Vice Admiral Ralph E. Wilson
Rear Admiral James L. Abbott, Jr.*
Rear Admiral Jamie Adair*
Rear Admiral Robert E. Adamson, Jr.*
Rear Admiral John W. Ailes, III
Rear Admiral Herbert S. Ainsworth*
Rear Admiral Frank Akers
Rear Admiral Herbert H. Anderson*
Rear Admiral Roy G. Anderson*
Rear Admiral Burton H. Andrews*
Rear Admiral Parker B. Armstrong*
Rear Admiral Jackson D. Arnold
Rear Admiral Frederick L. Ashworth
Rear Admiral Dean L. Axene*
Major General George C. Axtell, Jr.*
Rear Admiral James V. Bartlett*
Rear Admiral Edgar H. Batcheller
Rear Admiral Richard W. Bates
Rear Admiral Robert L. Baughan, Jr.*
Rear Admiral Marmaduke G. Bayne*
Rear Admiral Charles Becker*
Rear Admiral Frederick J. Becton
Rear Admiral John K. Beling*
Rear Admiral David B. Bell
Rear Admiral Fred G. Bennett*
Rear Admiral Allen A. Bergner*
Rear Admiral Philip A. Beshany
Rear Admiral Abel T. Bidwell
Major General Arthur F. Binney
Rear Admiral Calvin M. Bolster
Rear Admiral John L. Boyes*
Rear Admiral Frank A. Braisted
Rear Admiral Harold M. Briggs
Rear Admiral William A. Brockett
Rear Admiral James A. Brown
Rear Admiral Henry C. Brutton
Rear Admiral Clarence R. Bryan*
Rear Admiral Charles A. Buchanan
Rear Admiral Thomas Burrowes
Rear Admiral Robert L. Campbell
Rear Admiral Milton O. Carlson
Rear Admiral Worrall R. Carter
Rear Admiral George L. Cassell*
Rear Admiral Robert W. Cavenagh
Rear Admiral Lester S. Chambers
Rear Admiral John D. Chase*
Rear Admiral Kenan C. Childers, Jr.*
Rear Admiral Ernest E. Christensen*
Rear Admiral Thomas J. Christman*
Rear Admiral Albert H. Clancy, Jr.*
Rear Admiral David H. Clark
Rear Admiral Henry G. Clark, CEC
Rear Admiral Sherman R. Clark
Rear Admiral Leonidas D. Coates, Jr.
Rear Admiral Philip P. Cole*
Rear Admiral Howard L. Collins
Rear Admiral Samuel M. Cooley, Jr.*
Rear Admiral Damon C. Cooper
Rear Admiral Joshua W. Cooper
Rear Admiral Roy T. Cowdrey
Rear Admiral Donald V. Cox*
Rear Admiral Richard S. Craighill
Rear Admiral Robert E. Cronin
Rear Admiral Philip Crosby*
Rear Admiral Robert R. Crutchfield*
Rear Admiral Charles A. Curtze
Rear Admiral John E. Dacey
Rear Admiral James A. Dare*
Rear Admiral Lawrence R. Daspit
Rear Admiral James R. Davis, CEC
Rear Admiral James W. Davis
Rear Admiral John B. Davis, Jr.*
Rear Admiral James C. Dempsey
Rear Admiral John H. Dick*
Rear Admiral Ernest W. Dobie, Jr.

Rear Admiral Joseph E. Dodson
Rear Admiral John W. Dolan, Jr.*
Rear Admiral William A. Dolan, Jr.
Rear Admiral James C. Donaldson, Jr.*
Rear Admiral Marshall E. Dornin
Rear Admiral Jack S. Dorsey
Rear Admiral Wallace R. Dowd, Jr.*
Rear Admiral Norman J. Drustrup, CEC
Rear Admiral Clifford H. Duerfeldt
Rear Admiral Donald T. Eller
Rear Admiral Robert B. Ellis
Rear Admiral Arthur G. Esch*
Rear Admiral Edward J. Fahy
Rear Admiral Eugene H. Farrell*
Rear Admiral James M. Farrin, Jr.
Rear Admiral Emerson E. Fawkes
Rear Admiral Richard E. Fenning*
Rear Admiral William E. Ferrall
Rear Admiral Francis J. Fitzpatrick*
Rear Admiral Eugene B. Fluckey*
Rear Admiral Bernard B. Forbes, Jr.*
Rear Admiral Norbert Frankenberger*
Rear Admiral Mason B. Freeman*
Rear Admiral Rowland G. Freeman, III*
Rear Admiral Laurence H. Frost
Rear Admiral Robert B. Fulton, II
Rear Admiral Walter D. Gaddis*
Rear Admiral Daniel V. Gallery
Rear Admiral Francis L. Garrett*
Rear Admiral Fillmore B. Gilkeson*
Rear Admiral Robert O. Glover
Rear Admiral Alexander S. Goodfellow, Jr.*
Rear Admiral Robert C. Gooding*
Rear Admiral Willard K. Goodney
Rear Admiral Arthur R. Gralla
Rear Admiral Emery A. Grantham*
Rear Admiral Edward E. Grimm
Rear Admiral Peter W. Haas, Jr.
Rear Admiral Mayo A. Hadden, Jr.*
Rear Admiral Ira F. Haddock, SC
Rear Admiral Frederick E. Haeberle
Rear Admiral Wesley M. Hague
Rear Admiral Grover B. H. Hall
Rear Admiral George G. Halvorson*
Rear Admiral William M. Harnish*
Rear Admiral Lloyd Harrison
Rear Admiral Clarence M. Hart*
Rear Admiral Hugh E. Haven
Rear Admiral Vincent P. Healey*
Rear Admiral Grover C. Heffner*
Rear Admiral James B. Hildreth*
Rear Admiral Clarence A. Hill*
Rear Admiral Wellington T. Hines
Rear Admiral Morris A. Hirsch
Rear Admiral George A. Holderness, Jr.
Rear Admiral Paul A. Holmberg
Rear Admiral Carl O. Holmquist*
Rear Admiral Ernest C. Holtzworth
Rear Admiral Leroy V. Honsinger
Rear Admiral Edwin B. Hooper*
Rear Admiral Lewis A. Hopkins*
Rear Admiral Harold A. Houser
Rear Admiral Herbert S. Howard
Rear Admiral Miles H. Hubbard
Rear Admiral Harry Hull
Rear Admiral William D. Irvin
Rear Admiral Joseph A. Jaap
Major General Samuel S. Jack
Rear Admiral David H. Jackson*
Major General Arnold W. Jacobsen
Rear Admiral Jack M. James*
Rear Admiral Ralph K. James
Rear Admiral Frank L. Johnson
Rear Admiral Frank C. Jones*
Rear Admiral Horace B. Jones, CEC
Rear Admiral Denys W. Knoll
Rear Admiral William E. Kuntz*
Rear Admiral Paul L. Lacy, Jr.*
Rear Admiral Foster M. Lalor, Jr.*
Rear Admiral David Lambert
Major General Frank H. Lamson-Scribner
Rear Admiral Vincent A. Lascara*
Rear Admiral Martin J. Lawrence
Rear Admiral William H. Leahy
Rear Admiral Kent L. Lee*
Rear Admiral William E. Lemos*
Rear Admiral Joseph W. Leverton, Jr.
Rear Admiral William H. Livingston*
Rear Admiral James C. Longino, Jr.*
Rear Admiral Theodore C. Lonnquest
Rear Admiral Almon E. Loomis
Rear Admiral Wayne R. Loud
Rear Admiral Charles H. Lyman, III
Rear Admiral Douglas H. Lyness*
Rear Admiral Harvey E. Lyon*
Major General William G. Manley
Rear Admiral Albert R. Marschall*
Rear Admiral Charles F. Martin
Rear Admiral Fowler W. Martin*
Rear Admiral Harry C. Mason*
Rear Admiral Brian McCauley*
Rear Admiral Thomas R. McClellan*
Rear Admiral William R. McClendon*
Rear Admiral Leo B. McCuddin*
Major General Keith B. McCutcheon
Rear Admiral John B. McGovern
Rear Admiral Eugene B. McKinney
Rear Admiral William R. McKinney*
Rear Admiral Kenmore M. McManes
Rear Admiral Philip S. McManus*
Rear Admiral Edwin E. McMorries*
Rear Admiral Robert W. McNitt*
Rear Admiral John H. McQuilken
Rear Admiral Wm. K. Mendenhall, Jr.
Major General Lewie G. Merritt
Rear Admiral Roderick O. Middleton*
Rear Admiral William Miller
Rear Admiral Benjamin E. Moore
Rear Admiral Michael U. Moore*
Rear Admiral Robert L. Moore, Jr.
Rear Admiral Armand M. Morgan
Rear Admiral Henry S. Morgan*
Rear Admiral Thomas H. Morton
Rear Admiral Albert G. Mumma
Rear Admiral William T. Nelson
Rear Admiral Charles A. Nicholson, II
Rear Admiral Robert H. Northwood, SC
Rear Admiral Ira H. Nunn
Rear Admiral Emmet O'Beirne
Rear Admiral Edward J. O'Donnell
Rear Admiral James B. Osborn*
Rear Admiral Roger W. Paine*
Rear Admiral Charles J. Palmer
Rear Admiral Lewis S. Parks
Rear Admiral Goldsborough S. Patrick
Rear Admiral Charles N. Payne, Jr.*
Rear Admiral John B. Pearson, Jr.
Rear Admiral Henry S. Persons
Rear Admiral Forrest S. Petersen*
Rear Admiral William F. Petrovic*
Rear Admiral Carl J. Pfingstag
Rear Admiral Richard H. Phillips
Rear Admiral Ben B. Pickett
Rear Admiral Paul E. Pihl
Rear Admiral Frank L. Pinney, Jr.
Rear Admiral Frank H. Price*
Rear Admiral Walter H. Price
Rear Admiral William M. Pugh, II*
Rear Admiral Schuyler N. Pyne
Rear Admiral James D. Ramage*
Rear Admiral Harry L. Reiter, Jr.
Rear Admiral Henry A. Renken
Rear Admiral Joseph E. Rice*
Rear Admiral Roland Rieve*
Rear Admiral Basil N. Rittenhouse, Jr.
Rear Admiral Walter F. Rodee
Rear Admiral William K. Romoser
Rear Admiral Gordon Rowe
Rear Admiral Donald Royce
Rear Admiral Edward A. Ruckner
Rear Admiral Thomas J. Rudden, Jr.
Rear Admiral George L. Russell
Rear Admiral Ben W. Sarver
Rear Admiral Raymond J. Schneider*
Rear Admiral Malcolm F. Schoeffel
Rear Admiral Floyd B. Schultz
Rear Admiral John A. Scott*
Rear Admiral Leslie H. Sell*
Rear Admiral John N. Shaffer
Rear Admiral Tazewell T. Shepard, Jr.*
Rear Admiral William B. Sieglaff
Rear Admiral Harry Smith
Rear Admiral James H. Smith, Jr*
Rear Admiral Levering Smith*
Rear Admiral Stuart H. Smith*
Rear Admiral John A. Snackenberg
Rear Admiral Edwin K. Snyder*
Rear Admiral Joseph E. Snyder, Jr*
Rear Admiral Philip W. Snyder
Rear Admiral Edward A. Solomons
Rear Admiral Nathan Sonenshein*
Rear Admiral Robert H. Speck
Rear Admiral Roger E. Spreen*
Rear Admiral Frederick C. Stelter, Jr.
Rear Admiral Edward C. Stephan
Rear Admiral William R. StGeorge*
Rear Admiral Earl E. Stone
Rear Admiral Charles W. Styer
Rear Admiral Elton W. Sutherling*
Rear Admiral Robert L. Swart
Rear Admiral William E. Sweeney
Rear Admiral Frank R. Talbot
Rear Admiral Raymond D. Tarbuck
Rear Admiral Arthur H. Taylor
Rear Admiral John McN. Taylor
Rear Admiral Theodore A. Torgerson
Rear Admiral George C. Towner
Rear Admiral David M. Tyree
Rear Admiral Lloyd R. Vasey*
Rear Admiral Frank Virden
Rear Admiral John R. Wadleigh
Rear Admiral George H. Wales
Rear Admiral Kenneth C. Wallace*
Rear Admiral Frederick B. Warder
Rear Admiral William W. Warlick
Rear Admiral Odale D. Waters, Jr.
Rear Admiral David A. Webster*
Rear Admiral Daniel K. Weitzenfeld*
Rear Admiral David F. Welch
Rear Admiral Thomas R. Weschler*

Rear Admiral Charles D. Wheelock
Rear Admiral Francis T. Williamson
Rear Admiral Frederick S. Withington
Rear Admiral Narvin O. Wittman*
Rear Admiral Kenneth L. Woodfin*
Rear Admiral Mark W. Woods
Rear Admiral Edward A. Wright
Rear Admiral Earl P. Yates*
Rear Admiral Elmer E. Yeomans

Rear Admiral Selectees:
Raymond W. Burk*
William F. Clifford, Jr.*
Stanley T. Counts*
Tyler F. Dedman*
James E. Forrest*
Dewitt L. Freeman*
Harry "E" Gerhard, Jr.*
Isham W. Linder*
Rupert S. Miller*
Robert G. Mills*
Henry S. Morgan, Jr.*
Arthur W. Price, Jr.*
Charles F. Rauch, Jr.*
Charles P. Tesh*
William Thompson*
John M. Tierney*
Harry D. Train, II*
Edward C. Waller, III*
James D. Watkins*

The following astronauts are alumni of the Naval Postgraduate School

Gerald P. Carr, U. S. Marine Corps

Eugene A. Cernan, U. S. Navy

Ronald E. Evans, U. S. Navy

Jack R. Lousma, U. S. Marine Corps

Edgar D. Mitchell, U. S. Navy

Robert F. Overmyer, U. S. Marine Corps

Paul J. Weitz, U. S. Navy

Rear Admiral A. Scott Goodfellow, Superintendent, discusses postgraduate education with Rear Admiral Alan B. Shepard, Jr., the first astronaut to receive flag rank.

HISTORY

The Naval Postgraduate School is in its 62nd year of providing advanced education for commissioned officers of the United States Navy. When it was established at Annapolis on 9 June 1909, only ten officers made up the class, three professors formed the faculty, and marine engineering was the only curriculum. It was called the Postgraduate Department of the U. S. Naval Academy.

The school suspended operations during World War I. When classes resumed in 1919, mechanical and electrical engineering were added to the course of instruction. Later, ordnance engineering, radio engineering, aerological engineering and aeronautical engineering were introduced as the Navy continued to recognize its need for officers with technical knowledge. The postgraduate department was renamed the United States Naval Postgraduate School, but still operated under the guidance of the Naval Academy.

In 1927 the General Line Curriculum was established to provide instruction which would acquaint junior line officers with modern developments within the Navy, and to broaden their professional knowledge for future command at sea. It remained an integral part of the school until World War II, when the general line students returned to the fleet. Enrollment in the other curricula continued to increase during the war years as the school grew to meet the needs of the Navy. After the 1945 armistice, the Navy began plans to move the Postgraduate School away from Annapolis and to improve its professional status. The post-war period also saw the General Line School re-established, this time at Newport, Rhode Island, and at Monterey, California. Between 1945 and 1948, Congress established the school as a separate activity under its own superintendent, created the office of academic dean, granted the superintendent authority to award the bachelor's, master's and doctor's degrees, and approved Monterey as the future home of the school.

After purchasing the former Del Monte Hotel and surrounding acreage, the Naval Postgraduate School was officially established on the West Coast on 22 December 1951. Five years later the Navy Management School joined the General Line School as a component of the Postgraduate School, and for the first time a Bachelor of Science curriculum was offered to selected officers who had not completed their undergraduate education. A further need for baccalaureate courses resulted in the inauguration of the Bachelor of Arts curriculum in 1961.

A year later the Chief of Naval Personnel authorized a major internal reorganization of the school. The management, engineering and general line schools merged, in effect making the Naval Postgraduate School a naval university, unified in policy, procedure and purpose.

The last major revision took place in January 1967 after considerable evaluation of curricula. Operations were shifted from a five term to a four-quarter academic calendar. This change allowed the school to eliminate obsolete and unnecessary material, and restructure course sequences to strengthen the study programs.

Since 1946 the School has awarded 5193 bachelor's degrees, 4686 master's degrees, 100 engineer's degrees, and 42 doctoral degrees. At the present time the major emphasis is on the graduate degrees.

ORGANIZATION AND FUNCTIONS

The Superintendent of the Postgraduate School is a rear admiral of the line of the Navy. His principal assistants are a Provost/Academic Dean who is the senior member of the civilian faculty; and three captains of the line — a Chief of Staff, a Director of Programs, and a Director of Military Operations and Logistics.

The academic programs and direct supporting functions are administered and operated through a unique organization composed of Curricular Offices and Academic Departments. The former are staffed by naval officers and civilian faculty members whose primary functions are three-fold: (1) academic counseling and military supervision of officer students; (2) curriculum development and management to insure attainment of professional and academic objectives; and (3) liaison with curricular sponsor representatives. Officer students in each curricula group pursue similar or closely related curricula. With most of these areas a common core program of study is followed for at least half the period of residency. Officer students are grouped into the following curricular programs areas:

Aeronautical Engineering
Electronics and Communications Engineering
Ordnance Engineering
Naval Engineering
Environmental Sciences
Management and Computer Science
Operations Research/Systems Analysis

Engineering Science
Baccalaureate

Objectives and details of curricula are described in the section beginning on page 26.

The teaching functions of classroom and laboratory instruction and thesis supervision are accomplished by a faculty which is organized into ten academic departments:

Aeronautics
Electrical Engineering
Government and Humanities
Material Science and Chemistry
Mathematics
Mechanical Engineering
Meteorology
Oceanography
Operations Research and Administrative Sciences
Physics

Over five-sixths of the teaching staff are civilians of varying professional rank and the remainder naval officers.

Detailed listings of faculty members and course offerings are contained in later sections of the catalogue.

The Academic Program organization described is supervised by the Director of Programs and a civilian Dean of Programs who collaborate to share jointly the responsibilities for planning, conduct and administration of the several educational programs.

The close tie between elements of this dual organization is further typified by the Academic Associates. These are individual civilian faculty members appointed by the Academic Dean to work closely with the Curricular Officers in the development and continuing monitoring of curricula — the Navy's needs being the responsibility of the Curricular Officer, and academic soundness being the responsibility of the Academic Associate.

The educational programs conducted at Monterey fall into several general categories:

a. Engineering and scientific education leading to advanced degrees.
b. Management education to the Master's level.
c. Undergraduate education leading to a first baccalaureate degree, either B.S. or B.A.

Supplementing category a. above is the Engineering Science program. The major portion of the officers selected for this program undergo two terms of refresher and prerequisite study. Those who are so motivated may be selected by the Superintendent for a two or three year engineering or science curriculum. Those not selected continue in a non-degree program with the primary objective of basic scientific education which will better prepare them for advanced functional training and/or general updating in technical areas.

Logistic service support is rendered by conventional departments such as Supply and Disbursing, Public Works, Dental, Public Affairs, etc., grouped organizationally under a Director for Military Operations and Logistics. Certain other officers such as that of the Comptroller are directly responsible to the Superintendent in a slightly modified but typical naval staff organization.

FACILITIES

The Naval Postgraduate School is located within the City of Monterey, and only a mile east of the downtown business area and the city's Fishermen's Wharf. The site of the School is the former luxury Del Monte Hotel of pre-World War II days. The beautifully landscaped campus contains most of the academic and administration buildings within the main grounds. There is an adjacent beach area for research and a nearby laboratory and recreation area. The total campus covers approximately 600 acres.

The Superintendent and central administrative officers, along with other service functions, are located in Herrmann Hall, the most prominent building on the campus because of its old Spanish architecture.

Most of the academic classrooms, laboratories, and offices are located in Spanagel, Bullard, Halligan, Root and Ingersoll Halls. The newest building is the 400,000 volume Dudley Knox Library which was completed early in 1972. Adjacent to the main academic buildings is King Hall, a large lecture hall used to seat the student body, faculty, and staff when occasions require.

STUDENT AND DEPENDENT INFORMATION

Monterey Peninsula and the cities of Monterey, Carmel, Pacific Grove, and Seaside, all within 5 miles of the School, provide community support for the officers of the Postgraduate School.

LaMesa Village, located 3 miles from the School, consists of former Wherry Housing and new Capehart Housing. There are a total of 1057 units of public quarters for naval personnel. An elementary school is located within the housing area. Limited housing for single students is available in the BOQ located on the main campus in Herrmann Hall.

Student services include a campus branch of Bank of America, Navy-Federal Credit Union, U. S. Post Office, Student Mail Center, Navy Exchange and a child care center. A large commissary is located at Fort Ord and is available to Navy personnel.

Medical facilities include a Dispensary, supported by the U. S. Army Hospital at Fort Ord (7 miles away), and the U. S. Navy Hospital at Oakland (120 miles away). A Dental Clinic is located in Herrmann Hall.

The center of campus social activity is the Commissioned Officers and Faculty Club, located in the old hotel building. Many of the beautifully appointed rooms, just as they were at the turn of the century, include a ballroom and Open Mess. Two beautiful chapels are located on the main campus.

Student wives and wives of allied officers are active in the Officer Student Wives Club, the International Wives Club, as well as a Little Theater group which puts on three productions a year.

Recreational facilities include a swimming pool, an 18-hole golf course, putting green, tennis courts, ping pong and badminton courts, basketball and volley ball courts, a softball diamond, picnic grounds, bowling lanes, driving range, archery range, and gymnasium. Included in the many activities which participate in competition off campus are Ladies Golf Association, Mens Golf Association, Soccer Club, Rugby Club, Lacross Club, Ski Club, Karate Club, Tennis Club, and basketball and softball teams. The School also has a very active Military Amateur Radio Station and a Navy Flying Club.

Personnel assigned to the Postgraduate School have a very active Sailing Association open to sponsors and their dependents as well as members of the faculty. Sailing conditions are among the finest on the West Coast with excellent weather prevailing from February through November. The School's recreation department schedules the five Shields Class Sloops and an El Toro dinghy on a first-come first-served basis. Classes for beginners and advanced sailing enthusiasts are conducted twice a year, following the January and July inputs. The School works closely with civilian yacht clubs to coordinate many sailing events throughout the year and, in addition, hosts the annual Navy West Coast Match racing championships.

TEXTBOOKS

The Naval Postgraduate School operates a bookstore under the Navy Exchange System. It stocks all required textbooks and related school supplies. Students are required to purchase their books either from the school or local bookstores, or from other students. A partial reimbursement of $25 per quarter is allotted so the net cost to each student depends on his curriculum and the number of books he retains for his personal library at quarter's end.

Prospective students desiring a copy of the Postgraduate School Catalogue may request one by sending a check for $1.25 to: Navy Exchange Bookstore, Naval Postgraduate School, Monterey, California 93940.

ADMISSIONS PROCEDURES

U. S. Navy officers interested in admission to one of the curricula offered at the Postgraduate School are referred to OPNAV Notice 1520, Subject: Postgraduate Educational Programs, which is published annually by the Chief of Naval Operations. This directive outlines the various educational programs available and indicates the method of submitting requests for consideration for each program.

A selection board is convened annually by the Chief of Naval Personnel to select officers, based upon professional performance, academic background, and ability, within quotas which reflect the Navy's requirements in the various fields of study available. Officers will be notified of selection by a OPNAV Notice at the earliest feasible date after the meeting of the selection board, or by official correspondence.

The curriculum numbers as assigned in the annual OPNAV Notice 1520 are repeated in the title of each curriculum and are also included in the list of curricula at the Postgraduate School on page 26 and the list of curricula conducted at civilian institutions on page 58.

Officers on duty with other branches of service are eligible to attend the Postgraduate School. They should apply in accordance with the directives promulgated by the Department of the Army, Department of the Air Force, Commandant U. S. Marine Corps, or the Commandant U. S. Coast Guard, as appropriate.

Military officers from Allied Countries may be admitted to certain curricula at the Postgraduate School. Such admission is subject to availability of quotas assigned to each country. Applications must be made through normal channels of communication and not sent directly to the Naval Postgraduate School. The academic standards described in this Catalogue for admission to each curricula must be met.

Anyone having questions regarding admission procedures may write to the Dean of Admissions, Naval Postgraduate School, Monterey, California 93940; or telephone 408-646-2391 or AUTOVON 479-2391.

Civilian students are not eligible to attend the Postgraduate School.

REFRESHER COURSES

After notification of selection, officers are encouraged to write to the Superintendent, Naval Postgraduate School, Monterey, California 93940, Code 0212, for a self-study mathematics (calculus) refresher course. This course, designed for completion in about 150 hours, will be of great assistance in improving mathematics background and restoring study habits. Officers are urged to undertake this program.

There is also a six-week's refresher period for graduate-degree programs in which mathematics, mechanics, physics, chemistry, FORTRAN programming, and reading improvement are offered. Students are encouraged to arrive early to take advantage of this preparatory period.

DEGREES, ACCREDITATIONS, AND ACADEMIC STANDARDS

The Superintendent is authorized to confer Bachelor's, Master's, Engineer's or Doctor's degrees in engineering or related fields upon qualified graduates

of the School. This authority is subject to such regulations as the Secretary of the Navy may prescribe, contingent upon due accreditation from time to time by the appropriate professional authority of the applicable curricula. Recipients of such degrees must be found qualified by the Academic Council in accordance with prescribed academic standards.

The Naval Postgraduate School was accredited in 1962 as a full member of the Western Association of Schools and Colleges. Initial accreditation as an associate member was given in 1955. Specific engineering curricula have been accredited by the Engineers' Council for Professional Development (ECPD) since 1949.

The Postgraduate School operates under a quarter system, with each term of instruction lasting 12 weeks. The last week of each quarter is set aside for examinations. In addition, there are two 2-week recesses during the academic year, one over Christmas and one during June-July.

Students' performance is evaluated on the basis of a quality point number assigned to the letter grade achieved in a course as follows:

Performance	*Grade*	*Point Value*
Excellent	A	4
	A—	3.7
	B+	3.3
	B	3
	B—	2.7
	C+	2.3
	C	2
	C—	1.7
	D+	1.3
	D	1
Failing	X	0
Incomplete	I	—
Withdrew Passing	W	—
Withdrew Failing	WX	0
Nongraded	N	—
Pass	P	—
Fail	F	—

Courses may be designated for P and F grading when approved by the Academic Department and the Academic Council. Hours earned by the grade of P shall be counted toward fulfilling course hours specified by the degree requirements.

A grade of Incomplete (I), if not removed within twelve weeks following the end of the term for which it was received, will be replaced by the grade "X". Exceptions must be individually approved by the Academic Council.

When the quarter hours value of a course is multiplied by the quality point number of the student's grade, a quality point value for the student's work in that course is obtained. The sum of the quality points for all courses divided by the sum of the quarter hour value of all courses gives a weighted numerical evaluation of the student's performance termed the Quality Point Rating (QPR). A student achieving a QPR of 3.0 has maintained a B average in all courses undertaken with a proper weight assigned for course hours. Satisfactory academic proficiency at the Naval Postgraduate School has been established at a QPR of 2.0 for all courses of a curriculum.

Officer students have no major duties beyond applying themselves diligently to their studies. It is expected that students will maintain a high level of scholarship and develop attributes which are associated with a scholar seeking knowledge and understanding. Program schedules are such that the student should anticipate spending several hours in evening study each weekday to supplement time available for this purpose between classes.

The courses listed in this Catalogue are assigned a level of academic credit by the numbers assigned.

0001-0999 No credit
1000-1999 Lower division credit
2000-2999 Upper division credit
3000-3999 Upperdivision or graduate credit
4000-4999 Graduate credit

The two numbers in parenthesis (separated by hyphens) following the course title indicate the hours of instruction per week in classroom and laboratory respectively. Laboratory hours are assigned half the value shown in calculating quarter hours for the credit value of the course. Thus a (3-2) course (having three hours recitation and two hours laboratory) will be assigned a credit value of 4 quarter hours.

ACADEMIC HONORS

PROFESSIONAL SOCIETIES. Students have the opportunity to attend many professional meetings held at the Naval Postgraduate School. Several local chapters provide for student membership. These include Eta Kappa Nu, Sigma Xi, Tau Beta Pi, as well as ACM (Association for Computing Machinery), AIAA (American Institute of Aeronautics and Astronautics), AMS (American Meteorological Society), ASME (American Society of Mechanical Engineers), ASNE (American Society of Naval Engineers), IEEE (Institute of Electrical and Electronics Engineers, Inc.), ORSA (Operations Research Society of America), and the Marine Technology Society.

DEAN'S LIST. Students who distinguish themselves academically are recognized at the end of each quarter by being placed on the Dean's List. This recognition is awarded to students who earn a Quality Point Rating of 3.65, or higher, while carrying a minimum academic load of 12 quarter hours.

GRADUATION WITH HONORS. The award of the Master of Science Degree may be made "With Distinction" when a student completes the degree requirements with a minimum of 32-quarter hours earned in residence and is in the upper 10% of the graduating class. The award of a Bachelor's Degree may be made "Cum Laude" when a student com-

pletes the degree requirements with a minimum of 60-quarter hours in residence and is in the upper 5% of the graduating class.

SIGMA XI. The Naval Postgraduate School has a Chapter of the Society of the Sigma Xi, an honorary society founded to recognize excellence in the scientific and engineering disciplines. Students who have demonstrated marked promise in their research work are considered for membership each year. The number elected is limited only by the quality of the research work done for a graduate degree.

MEWBORN STUDENT RESEARCH AWARD. This award affords recognition for exceptional research talent. It is awarded annually to a student in a program of graduate scientific or engineering studies, leading to an advanced degree, whose thesis exhibits sound scholarship and outstanding research ability.

CAPTAIN J. C. WOELFEL AWARD. This award is given annually to the United States Naval officer student receiving an advanced degree in the Naval Engineering Programs who has demonstrated the most outstanding academic record, and at the same time possesses those attributes best exemplifying a Naval Officer.

W. RANDOLPH CHURCH AWARD. This award is given annually to a student on the basis of his performance in mathematics courses. The criteria for selection will include evidence of initiative, scholarly attitude and mathematical maturity. The student need not be a mathematics major, nor must he be a graduate at the time of presentation.

NAVAL ELECTRONIC SYSTEMS COMMAND AWARD IN ELECTRONICS ENGINEERING. This award will be given semi-annually to a Master of Science candidate in the Advanced Electronics Engineering Program who has a most outstanding academic record and whose qualities indicate an outstanding military officer.

DIPLOMAS OF COMPLETION

Diplomas of Completion are issued to students completing programs which do not offer a degree. To establish eligibility for a Diploma of Completion, a student must obtain an overall QPR of 2.0 or better. Where applicable, students obtaining a QPR of 3.75 or better will receive Diplomas of Completion "With Distinction."

REQUIREMENTS FOR THE BACCALAUREATE DEGREE

1. The Bachelor of Science or the Bachelor of Arts Degree may be awarded for successful completion of a curriculum which has been approved by the Academic Council as meriting the degree. Such curricula shall conform to current practice in other accredited institutions and shall contain a well-defined major.

2. General Postgraduate School minimum requirements for the Baccalaureate Degree are as follows:

a. 180 quarter hours of which at least 72 hours must be at the upper division level from course numbered at or above 2000.
b. One academic year in residence.
c. 36 quarter hours in the Humanities and the Social Sciences.
d. 36 quarter hours in Mathematics and the Physical Sciences.
e. Completion of the departmental requirements for a well-defined major.
f. A quality point rating of at least 2.00 in all courses taken at the Postgraduate School as well as in the courses in the major.

REQUIREMENTS FOR THE MASTER OF ARTS AND MASTER OF SCIENCE DEGREES

1. The Master's Degree may be awarded for successful completion of a curriculum which has the approval of the Academic Council as meriting the degree. Such curricula shall conform to current practice in accredited institutions and shall contain a well-defined major.

2. General Postgraduate School minimum requirements for the Master's Degree are as follows:

a. 32 quarter hours of graduate level credits.
b. A thesis or its equivalent is required. If the thesis is waived, at least 8 quarter hours of approved courses 4000-4999 shall be substituted for it.
c. One academic year in residence.
d. Departmental requirements for the degree in a specified subject.

3. Admission to a program leading to the Master of Science degree requires a baccalaureate degree with appropriate undergraduate preparation for the curriculum to be pursued. If a student enters the Postgraduate School with inadequate undergraduate preparation, he will be required to complete the undergraduate prerequisites in addition to the degree requirements.

4. In order to qualify for a Master's Degree, a student first must be admitted to candidacy for the degree. Application for admission to candidacy must be made subsequent to completion of 50% of his curriculum, and prior to completion of 75% of the curriculum. Students having a quality point rating of 3.00 or greater in all courses of their curricula are qualified for admission to candidacy. Students having a total quality point rating from 2.50 to 2.99, inclusive, may be admitted to candidacy by the Academic Council upon recommendation of the Chairman of the Department of the major. Students with a total quality point rating below 2.50 will be ineligible for admission to candidacy.

5. To be eligible for the Master's Degree, the student must attain a minimum average quality point

rating of 3.00 in all the graduate level courses in his curriculum and either 2.50 in the remaining courses or 2.75 in all courses of the curriculum.

REQUIREMENTS FOR THE DEGREE: ENGINEER

1. The Engineer degree may be awarded for successful completion of a curriculum which has the approval of the Academic Council as meriting the degree.

2. Minimum Postgraduate School requirements for the degree of Engineer are as follows:

a. 72 quarter hours of graduate level courses including at least 30 hours in courses 4000-4999.
b. An acceptable thesis.
c. One academic year in residence.
d. Departmental requirements for the degree in a specified Engineering field.
e. A quality point rating of at least 3.00 in all graduate courses in the curriculum and either 2.50 in the remaining courses or 2.75 in all courses of the curriculum.

REQUIREMENTS FOR THE DOCTOR'S DEGREE

1. The degree Doctor of Philosophy is awarded as a result of very meritorious and scholarly achievements in a particular field of study which has been approved by the Academic Council as within the purview of the Naval Postgraduate School. A candidate must exhibit faithful and scholarly application to all prescribed courses of study, achieve a high level of scientific advancement, and establish his ability for original investigation.

2. Any program leading to the degree Doctor of Philosophy shall require the equivalent of at least three academic years of study beyond the baccalaureate level, with at least one academic year being spent at the Naval Postgraduate School.

3. A student seeking to become a candidate for the Doctorate shall hold a Bachelor's degree based on a curriculum that included the prerequisites for full graduate status in the department of his major study, or he shall have pursued successfully an equivalent course of study. The student shall submit his previous record to the Chairman of the Department of his proposed major subject for determination of his acceptability as a Doctoral student. The method of screening applicants shall be the responsibility of the department, but it will usually involve a written or oral screening examination. No applicant shall take such an examination more than twice.

4. The Doctoral Committee will be nominated by the Department Chairman and approved by the Academic Council. The Committee will consist of five or more members from at least three departments. One member of this Committee may be from another university or appropriate institution. Each member will have earned the doctorate; this requirement may be waived for not more than one of the committee members, if the Academic Dean certifies that selection of the proposed member is in the best interests of the School. At the time that the above Committee is submitted for approval, or at a subsequent time no later than when the student is advanced to candidacy for the doctorate, the major Deparment Chairman shall designate, for the approval of the Academic Council, the member of the Doctoral Committee who shall serve as Dissertation Supervisor. The Doctoral Committee has responsibility for the program of study, which shall include one or more minor fields, suitable to the needs of the student and the requirements for award of the Doctorate.

5. After his program of study in the major and minor fields has been essentially completed, the student shall be given by his Doctoral Committee a comprehensive Qualifying Examination which shall include both written and oral parts. The oral examination will be administered by the entire Doctoral Committee. The Academic Council will be invited. Passage of the Qualifying Examination will require a unanimous vote of the Doctoral Committee. No student may take the Qualifying Examination more than twice. The result of the examination, whether pass or fail, shall be reported to the cognizant Curricular Officer and to the Academic Council. Each member of the Doctoral Committee shall sign the report.

6. The language requirement is to be satisfied by the student who will demonstrate, before an examiner appointed by the Academic Dean, a satisfactory ability to read work related to his special field of study in at least one language in addition to English. The normally accepted languages are French, German or Russian. However, if the student can demonstrate that enough current technical literature in his major field exists in another language, the Doctoral Committee may approve this language. The required proficiency in the language should be gained early, both to avoid disruption of the research at a critical time, and also to insure that the necessary practice can be combined with learning the literature in the field of specialization. The program of study shall include one or more minor fields, as specified by the Doctoral Committee, suitable to the needs of the student and to the research problem he will undertake. The minor requirement will be satisfied by procedures specified by the department of the minor; these may include written or oral examination, completion of sequence of courses, etc. Upon successful completion of the language requirement and the comprehensive examinations, the student becomes eligible for advancement to candidacy.

7. The distinct requirement of the Doctorate is the successful completion of a scholarly investigation leading to an original and significant contribution to knowledge in the candidate's major area of study. The subject of the investigation must be approved by the Doctoral Committee, who will report the approved subject to the Academic Council. This

report must be made no later than the time of request for advancement to candidacy. In any event, the candidate must devote at least six months to research, following the date of advancement to candidacy, before he may expect to present himself for the final examination.

8. When the dissertation research has been completed and a draft has been prepared to the satisfaction of the Dissertation Supervisor, a copy shall be submitted to each member of the Doctoral Committee for approval. Approval by the committee members shall signify the Committee's acceptance of the draft as a basis for the final defense-of-dissertation examination. After obtaining unanimous acceptance of the draft from the Doctoral Committee, the Chairman shall schedule an oral final examination. This examination should not be scheduled earlier than one week following the submission of the draft of the dissertation to the Doctoral Committee. The Academic Council shall be invited. In the final examination, the candidate will present and defend his dissertation and he shall be subject to such questions as the Doctoral Committee and the Academic Council may deem appropriate. Passage of the examination requires a unanimous vote of the Doctoral Committee. The results of the final examination (whether pass or fail) shall be reported to the Academic Council, the report bearing the signatures of all the members of the Committee. If the candidate is passed, this report shall also include:

a. Certification of acceptance of the dissertation.
b. Nomination of the successful candidate for the award of the degree, Doctor of Philosophy.

9. After receiving the report of the Doctoral Committee, the Academic Council will make the final decision whether or not to recommend the candidate to the Superintendent of the Naval Postgraduate School for the award of the Doctor of Philosophy degree.

COOPERATIVE DOCTORAL PROGRAM

The Cooperative Doctoral Program provides civilian scientists and engineers of the Defense Department the opportunity to extend their education to the doctoral level. Candidates for the program must be civilian employees who have already attained the Master's degree, or its equivalent. Acceptance into the program will be based on evaluation of the candidate's academic record and professional experience by the Postgraduate School. The evaluation will usually include administering the same screening examination given to resident officer students.

Successful candidates will be appointed to the Faculty of the Postgraduate School with the rank of Visiting Instructor. The home organization of the candidate is expected to provide his billet under a non-reimbursable billet arrangement. The Visiting Instructor will spend six to eight hours per week on faculty duties and the balance on his graduate studies. An adequately qualified candidate should be able to complete his doctorate in about two and a half years of residence.

Doctoral programs are available in the following disciplines: aeronautics, electrical engineering, mechanical engineering, meteorology, oceanography, operations research, and physics. Interested candidates are invited to address letters of inquiry to the Academic Dean, Naval Postgraduate School, Monterey, California 93940.

NAVAL POSTGRADUATE SCHOOL FOUNDATION

The Foundation is a non-profit corporation whose purposes are:

> "to solicit, receive, and administer contributions and make donations and dispense charitable contributions . . . and otherwise aid, encourage and support the traditions of the Naval Postgraduate School . . ."

The corporation was formed in December 1970, and has since served as a vehicle by which large and small tax-exempt gifts have been easily and quickly given to the School. These gifts are all applied to those needs or purposes which would otherwise — in these days of severe fiscal restraint — be poorly- or not-at-all funded.

The Rear Admiral John Jay Schieffelin Award for Excellence in Teaching was endowed through the Foundation. A black granite sculpture, FLIGHT, located in the Dudley Knox Library, was donated to help publicly honor the recipients of this prestigious and valuable award.

The School's Sailing Association owes all of its present assets (five Shields Class sloops and one El Toro dinghy) to donations made to the Foundation. Small donations have also been received from some "friends of the Library" who wished to create a small but meaningful and useful memorial.

The Directors of the corporation are civilians, except for the Superintendent who serves to assure that only gifts appropriate to the School are accepted.

Individuals wishing to participate in the work of the Foundation may write to the Secretary, Naval Postgraduate School Foundation, Inc., Naval Postgraduate School, Monterey, California 93940.

SUPERINTENDENT'S GUEST LECTURE PROGRAM

Throughout the Academic Year lectures will be presented on Tuesday afternoons in King Hall for students, faculty and staff. Eminently qualified civilian and military authorities from a wide range of fields and accomplishments will speak on subjects of current and historical interest in international, government, sociological, and military affairs. Occasionally speakers are presented in the evening with wives also invited to attend. The primary purpose of this series is to inform as well as to stimulate and challenge the thinking of the officer students in areas outside of their immediate academic pursuits.

W. R. CHURCH COMPUTER CENTER

STAFF

Douglas George Williams, Professor and Director (1961)*; M.A. (Honours), University of Edinburgh, 1954.

Roger Rene Hilleary, Manager, User Services (1962); B.A., Pomona College, 1953; M.S., Naval Postgraduate School, 1970.

Edward Norton Ward, Manager, Systems Programming, 1959); B.A., University of California at Los Angeles, 1952.

David Fredric Norman, Manager, Operations, (1969).

Lois May Brunner (1961); B.S., Naval Postgraduate School, 1968.

Hans Welter Doelman (1967); B.S., University of California at Berkeley, 1956.

Richard Eugene Donat (1968); B.S., California State Polytechnic College, 1967.

Kathleen Marie Eisenhardt (1970); B.S.M.E., Brown University, 1969.

William David Ehrman (1968); B.S., Colorado State University, 1965; M.S., Colorado State University, 1968.

Clarence William Kellogg (1968); A.A., Monterey Peninsula College, 1969.

Gerard Paul Learmonth (1969); B.S., New York University, 1966; M.B.A., New York University, 1972.

Bernadette Requiro Peavey (1967); B.A. University of California at Berkeley, 1963.

Sharon Dill Raney (1964); B.S., California State Polytechnic College, 1964.

Kathryn Betty Strutynski (1967); B.S., Brigham Young University, 1953.

Arturo Valles (1970); B.S., Trinity University, 1957.

Robert Stephen Walton (1961); B.S., Massachusetts Institute of Technology, 1949.

Pimporn Chavasant Zeleny (1968); B.S. (Honours), Chulalongkorn University in Bangkok, 1955; M.S., Syracuse University, 1958.

**The year of joining the Postgraduate School is indicated in parentheses.*

The Naval Postgraduate School was one of the first institutions to use digital computers in their educational programs. The first machine, an NCR 102A, was installed in 1954 and operated by the Department of Mathematics. A central Computer Facility was created in 1960 as an organizational unit separate from the academic departments. In December, 1969, the Facility was renamed the "W. R. Church Computer Center" in memory of Professor Church, Chairman of the Department of Mathematics (1947-66), who recognized very early the value of computers in education and was instrumental in obtaining the early computers at the School.

The many services of the Center are available to all faculty, staff, and students of the School for use in connection with instruction, research, or administrative activities.

These services are based on an IBM 360, Model 67 computer system which was installed in April, 1967. The present hardware complement includes two Model 67 processing units; four different levels of storage, including 786 thousand bytes of core, four million bytes on a drum, approximately 291 million bytes on disk devices and 400 mililon bytes on a data cell unit; four magnetic tape units; two high-speed plotters, thirty remote typewriter terminals, and an IBM 2250 Graphical Display Uni with light-pen and programmed function keybod. The two processors are identical and can access directly, or control, all components of the system including core storage modules, input/output controllers and devices. The resources of the system can be allocated easily to create different operational environments.

The Center offers users two modes of operational services, viz., batch processing and multi-access timesharing. Both operating systems support a great variety of programming languages, libraries of subroutines and other software facilities. Language support includes FORTRAN IV, WATFOR, Assembler, COBOL, PL/1, BASIC, ALGOL-W, GPSS, LISP, CSMP.

The School has a heavy commitment to computers consistent with their present and future role in military operations. All of the academic curricula have been affected by the presence of computers on campus. The percentage of active student and faculty participation in the computer field is at a level probably unequalled at any other educational institution. All graduate students take at least one course in computer science. They are introduced to the computer early in their curricula at the Naval Postgraduate School and encouraged to use it in subsequent course work and research.

The Computer Center supports a wide variety of specialist courses in computer science offered in the Departments of Electrical Engineering, Mathematics, and Operations Research and Administrative Sciences. The School offers two graduate degrees in the data processing field, vis., M.S. (Computer Systems Management) since 1963, and M.S. (Computer Science) since 1967.

The Center has a staff of 32 people of whom 16 are mathematician/programmers. The professional staff provides a consulting service in applications programming, systems programming and problem formulation to students and faculty members. They participate in an active research and development program directed primarily towards improving the present operational environment or introducing new programming facilities to users. Current projects include work on systems measurement, improvement of operating systems, graphical data processing, timesharing facilities, and numerical analysis.

Aerial view of the Naval Postgraduate School campus, showing the Dudley Knox Library which was dedicated on 10 March 1972.

THE DUDLEY KNOX LIBRARY

STAFF

George Ridgely Luckett, Professor and Director of Libraries (1950)*; B.S., Johns Hopkins University, 1949; M.S., Catholic University, 1951.

Paul Spinks, Associate Professor and Associate Director of Libraries (1959); B.A., University of Oklahoma, 1958; M.S., 1959.

Edgar Raymond Larson, Assistant Professor and Read Services Librarian (1959); B.A. University of Washington, 1939; B.S., 1950.

Georgia Plummer Lyke, Reference Librarian (1952); A.A., Hartnell College, 1940.

Diane Shirley Nixon, Reference Librarian (1969); B.A., California State College, 1968; M.S., University of Southern California, 1969.

Janusz Ignacy Kodrebski, Assistant Professor and Head Catalog Librarian (1956); Diplomat of the National War College, Warsaw, Poland, 1938; M.S., University of Southern California, 1955.

Elsa Marie Kuswalt, Catalog Librarian (1958); B.A., University of California at Berkeley, 1957; M.L.S., University of Southern California, 1966.

Louis Oven, Catalog Librarian (1969); B.A., Monterey Institute of Foreign Studies, 1964; M. A. 1968; M.A., University of California at Berkeley, 1968.

Alice Marie Stude, Catalog Librarian (1969); B. A., University of Minnesota, 1930; M.S., University of California at Berkeley, 1961.

Noel William Johnson, Assistant Professor and Head Technical Reports Librarian (1970); B.A., University of Nevada, 1949; B.L.S., University of California at Berkeley, 1954.

Joanne Marie May, Technical Reports Librarian (1971); B.A., Chestnut Hill College, 1964; M.L.S. Villanova University, 1967.

Cleo Elizabeth Peterson, Technical Reports Librarian (1958); A.A., Red Oak College, 1938.

Frances Emanuela Maria Strachwitz, Technical Reports Librarian (1970); B.S., Dominican College of San Rafael, 1951; M.A., University of Denver, 1968.

Mary Therese Britt, Acquisitions Librarian (1966); B.S., College of St. Catharine, 1947.

Donna Marsalis Glenn, Bibliographer (1971); B. A., University of Colorado, 1969; M.L.S., University of California, Berkeley, 1970.

**The year of joining the Postgraduate School is indicated in parentheses.*

DESCRIPTION

The Dudley Knox Library, a new building occupying 50,000 square feet, was dedicated in 1972. The collections housed therein serve the research and instructional needs of the community comprising students, faculty, and staff of all departments of the Postgraduate School. They embrace an active collection of 130,000 books, bound periodicals and pamphlets, 150,000 technical documents, over 2,500 periodical works currently received, and 65,000 microcards and microfiche. These materials parallel the School's curricular fields of engineering, physical sciences, industrial engineering, management, naval sciences, government and humanities.

The Reference Library provides the open literature sources such as books, periodicals and journals, indexes and abstracting services, pamphlet materials and newspapers. It also furnishes facilities for microfilm reading and microfilm printing, for photographic and contact reproduction of printed matter, and for borrowing, from other libraries, publications not held in its collection.

The Technical Reports and Classified Materials Section is the principal repository for technical research documents received by the School. It houses 150,000 documents, 50% of which are classified, and exercises control over the microcard and microfiche collection. A machine information storage and retrieval system that utilizes the School's computer facilities is available for literature searches of documents received since November 1960. An SDI (Selective Dissemination of Information) service, designed to broaden the scope of the Library's automated services to the Postgraduate School, is also available. Future plans include the utilization by the Library of a remote terminal unit, which will facilitate the generation of rapid literature searches.

The Christopher Buckley, Jr., Library is located on the second floor of the Library. It is a collection of some 8,000 volumes pertaining principally to naval history and the sea. The establishment of this collection was made possible by the interest and generosity of Mr. Christopher Buckley, Pebble Beach, California, who began donating books to the School for this Library in 1949.

Lobby of the Dudley Knox Library

Herrmann Hall, the main administration building, formerly the Old Hotel Del Monte

CURRICULAR OFFICES and PROGRAMS

CURRICULA AT THE POSTGRADUATE SCHOOL

Curriculum	*Curriculum Number*	*Length*	*Convening Dates*
Advanced Science			
Chemistry	380	24-27 mo.	March, September
Hydrodynamics	380	24-27 mo.	March, September
Mathematics (Applied)	380	24-27 mo.	March, September
Material Science	380	24-27 mo.	March, September
Physics (General)	380	24-27 mo.	March, September
Physics (Nuclear)	380	24-27 mo.	March, September
Aeronautical Engineering	610	24-33 mo.	March, September
Baccalaureate			
Bachelor of Arts	461	24 mo.	January, July
Bachelor of Science	461	24 mo.	January, July
Electronics and Communications Engineering			
Communications Engineering	600	27-36 mo.	March, September
Communications Management	620	18 mo.	March, September
Engineering Electronics	590	27-36 mo.	March, September
Engineering Science	460	6-12 mo.	March, September
Environmental Sciences			
Advanced Meteorology	372	24 mo.	March, September
Oceanography	440	24 mo.	March, September
Immediate Graduate Education Program (IGEP)		12 mo.	January, July
Management and Computer Science			
Computer Science	368	21 mo.	September
Computer Systems Management	367	15 mo.	March, September
Management	814 and 817	12 mo.	January, July
Systems Acquisition Management	816	18 mo.	March, September
Naval Engineering			
Electrical Engineering	570	27-36 mo.	March, September
Mechanical Engineering	570	27-36 mo.	March, September
Operations Research/Systems Analysis	360	24 mo.	March, September
Ordnance Engineering			
Nuclear Science (Effects)	521	27 mo.	March, September
Ordnance Systems Engineering	530	27-36 mo.	March, September
Engineering Acoustics	535	27 mo.	September

ADVANCED SCIENCE PROGRAMS

CURRICULUM NUMBER 380

Chemistry
Hydrodynamics
Material Science
General Physics
Nuclear Physics
Applied Mathematics

OBJECTIVE — To prepare selected officer personnel to deal with the problem of fundamental and applied research in the fields of general physics, nuclear physics, hydro-dynamics, chemistry, material science, and applied mathematics.

QUALIFICATIONS FOR ADMISSION — Officers nominated for Advanced Science Curricula are selected from among those first-year students enrolled in technical curricula at the Postgraduate School who apply for the Advanced Science Program. Applicants are carefully screened and only those having a very good academic background and who appear to have an excellent chance of succeeding in their chosen field are nominated to the Chief of Naval Personnel.

DESCRIPTION — Officers selected for Advanced Science Curricula complete their first year at the Naval Postgraduate School, and may spend their second and third years of study either at the Naval Postgraduate School or a civilian university. The curriculum for each officer is arranged from courses selected to suit the needs of the Navy, to develop the capabilities of the individual student, and to meet the ultimate objective of his specialty.

The Advanced Science Curricula normally lead to the Master of Science degree for those officers meeting the requirements for that degree.

Selected Naval Academy, NROTC, and OCS graduates may enter directly into a graduate program (IGEP) and obtain a Master's degree upon completion of four quarters' course work, including an acceptable thesis.

A painting of Father Junipero Serra landing in Monterey (3 June 1770) is on the wall of the lobby of the old Hotel Del Monte (now Herrmann Hall, the main administration building). This lobby has since been converted into a beautiful chapel.

AERONAUTICAL ENGINEERING PROGRAMS
CURRICULUM NUMBER 610

DONALD WILLIAM MATHEWS, Commander, U. S. Navy; Curricular Officer; B.S. in Engr., University of California at Berkeley, 1953; B.S. in Aero Engr., Naval Postgraduate School, 1960; Ae. E., Stanford University, 1961; Armed Forces Staff College, 1966.

ROBERT DIEFENDORF ZUCKER, Academic Associate; B.S. in M.E., Massachusetts Institute of Technology, 1946; M.M.E., University of Louisville, 1959; Ph.D., University of Arizona, 1966.

JAMES BARNETT POLAND, Commander, U. S. Navy; Assistant Curricular Officer; B.S., Naval Academy 1953; B.S., in Aero. Engr., Naval Postgraduate School, 1967.

OBJECTIVE — To provide graduate engineering education for aeronautical naval officers primarily to broaden their capacity for original throught, develop their analytical ability for problem solving, and prepare them for positions in technical management and other assignments throughout their career in naval aviation.

Although technical expertise and engineering skill may be directly applied in early years in some cases, the greatest value to the Navy of the aeronautical engineering program comes from the creative application of analytical and problem-solving abilities to Navy tasks. Creativity and expanded capacity for original thought are emphasized in thesis-centered curricula. Technical and scientific confidence for work in the technical arena of the Naval Air Systems Command and related naval activities is gained by all graduates.

QUALIFICATIONS FOR ADMISSION — Direct Input — Normally students receive orders to the Aeronautical Engineering Curriculum after completion of their first operational tour, and therefore have been away from college from four to five years. Entrance requirements for the Department of Aeronautics are outlined separately in the catalogue. In general, a baccalaureate degree with grade average of B or better in mathematics, physical sciences, and engineering is required. Minimum course work usually includes completion of mathematics through differential and integral calculus, one year of engineering physics, and one year of mechanics. Additional undergraduate coverage in basic engineering, electrical engineering, mathematics and chemistry is desirable. Specific questions may be answered by calling the Curricular Officer (AUTOVON 479-extension 2491).

Indirect Input — Students with a baccalaureate who do not meet the requirements for direct input receive orders to Aeronautical Engineering via Engineering Science (610 via 460) for one or more quarters to prepare for the Aeronautics Program. Selected students without a baccalaureate degree may complete it in the Baccalaureate Program before transferring to the Aeronautical Engineering Curriculum. In each case the emphasis for qualification is on currently demonstrated academic performance to insure a high probability of success for the student.

DESCRIPTION — Officers qualified for the Direct Input, convening twice yearly in the March and September quarters, are ordered to the Postgraduate School six weeks early to a rapid refresher course in calculus, statics, and FORTRAN programming. At the completion of the refresher period, Direct Input students are joined by Indirect Input students from Engineering Science. These Indirect Input students have completed a variety of courses in Engineering Science to eliminate academic deficiences and complete a slower-paced refresher program. The combined group completes a three quarter common core of upper division and partial graduate credit courses to prepare for graduate status. Core courses in each quarter cover the areas of mathematics, fluids, solids, and aerodynamics. Students without previous undergraduate background in electrical engineering who desire to study in aeroelectronics make the appropriate substitution for solids courses in the core. The emphasis in the core is to round out and update aeronautical engineering background, demonstrate potential for full graduate school study, and identify specific areas of interest for thesis study and individualized specialization. Exceptional students who have previously completed courses in core subjects are encouraged to validate them, when qualified, in order to take either additional courses of interest or an accelerated program.

Aeronautical engineering students normally complete five additional quarters of graduate work leading to the degree of Master of Science in Aeronautical Engineering. Students who have recently earned a degree with major in Aeronautics may apply for admission directly to the graduate program and obtain a Master of Science degree upon completion of four quarters of work, including an acceptable thesis.

Officers demonstrating a particularly strong academic performance in technical subjects in the core are nominated for an eight-quarter program beyond the core leading to both the Master of Science in Aeronautical Engineering and the advanced degree of Aeronautical Engineer. This program also includes a six-week experience tour at an industrial activity. Also at the end of the core a few officers with strong academic performance are nominated to complete the Dual Masters program in eight additional quarters. In this new program the student first completes the requirements for the Master of Science in Aeronautical Engineering and then the requirements for the Master of Science in Management.
A few exceptionally well-qualified officers are selected each year for the four year doctoral program.

All graduate students complete a thesis as a part of their graduate degree requirements. This acts as a synthesis for their graduate education.

The degree programs described above all include several courses beyond the specified degree requirements outlined in the Department of Aeronautics section of this catalog. These additional courses include subjects in electrical engineering, material science, and management that are considered particularly relevant to Navy needs and naval officer career development by the Naval Air Systems Command.

All Aeronautical Engineering graduates will receive subspecialty qualification 81XX codes as listed in current OPNAVINST 1211.6 series.

The outlines listed below show the framework for individual program planning and describe the various specialty areas normally studied. In all cases, standard programs with specific courses have been approved and are on file for use. However, emphasis is on individual program development through academic and career counseling and student participation.

AERONAUTICAL ENGINEERING

Direct Input

Six-Week Refresher

AE	0110	Review of Statistics and Elementary Strength of Materials	4- 4
MA	0112	Refresher Mathematics	5- 5
CS	0110	FORTRAN Programming	3- 0
			12- 9

Common Core

First Quarter

AE	2021	Aero-Structures I	3- 2
AE	2031	Vehicle Aerodynamics I	3- 2
AE	2041	Basic Fluid Mechanics	3- 2
MA	2047	Linear Algebra and Vector Analysis	4- 0
AE	0610	Analog Computers	0- 2
			13- 8

Second Quarter

AE	2022	Aero-Structures II	3- 2
AE	2032	Vehicle Aerodynamics II	3- 2
AE	2042	Engineering Thermodynamics	3- 2
AE	2801	Introduction to Aero Laboratories	0- 3
MA	3130	Differential Equations	4- 0
			13- 9

Third Quarter

AE	3015	Engineering Dynamics	3- 2
AE	3033	Vehicle Aerodynamics III	3- 2
AE	3043	Fundamental Concepts of Gasdynamics	3- 2
AE	3811	Solid Mechanics Laboratory	0- 3
MA	3173	Complex Variables and Laplace Transforms	4- 0
			13- 9

Selection for various degree programs is made based on academic performance, career availability, and personal desires of the student after completion of the common core.

SPECIALTY COURSES

At the end of the core, students have an understanding of the various specialty areas in the Aeronautical Engineering Curriculum. At this point students select a thesis topic and faculty advisor and confirm their program of study in one of the following specialty areas.

Aerodynamics (Flight Dynamics) includes coverage of the stability and control parameters of a flight vehicle in both pilot-controlled and automatic-controlled modes. Both manned and unmanned vehicles are investigated. Topics include automatic landing systems, missile control, and optimal design.

In *Aerodynamics (Gasdynamics)*, operation of flight vehicles in the broad spectrum ranging from hovering flight to hypersonic reentry is investigated, with particular emphasis being placed on the behavior of the gas (air or near-space) in which the vehicle is operating. Subsonic, transonic, supersonic, hypersonic, and plasma flows are covered in detail.

The *Information and Control* specialty provides knowledge in depth in computer-flight vehicle interface in operation of modern and projected air weapons systems. Computer technology, capability and applications to the flight vehicle and its mission are stressed.

Flight Propulsion (Rocket/Turbomachinery) develops fundamentals of fluid dynamics, thermodynamics, and turbomachinery to provide a generalized flight propulsion background. Emphasis on thesis work provides the basic difference in the assigned specialty of rockets or turbomachinery.

For *Flight Structures*, a study in depth of the mechanics of solids is followed by investigations of the behavior of structural components under conditions of static and dynamic (including aero-elastic) loads (both steady and non-steady). Free, forced, and self-excited vibrations; flutter, gusts, buffet, and stall effects; and wing divergence and control reversal are typical of the topical coverage.

In the *Air Weapons* specialty, the studies of chemical explosives and blast and shock effects are emphasized and supplement coverage of core aeronautics courses to prepare the graduate to work in the sub-area of conventional ordnance in air weapons systems.

The *Aeroelectronics* specialty builds upon a background of aeronautics core courses. In-depth studies in electrical and electromagnetic fundamentals and applications in electronics prepare the graduate to serve as a specialist in avionics of both manned and unmanned flight vehicles in naval air weapons systems programs.

An *Aero/Space Physics* specialty, leading to the degree of Aeronautical Engineer, includes the study of electromagnetics, quantum mechanics, and space and near-space physics. This specialty sequence prepares the graduate to participate in any of several areas in Navy programs involving missile and space technology. Only a three-year Aero/Space Physics program is available.

ELECTIVE COURSES

Aeronautical Engineering elective courses are chosen from appropriate level courses offered by the Department of Aeronautics and are used to develop each student's technical knowledge and background for thesis research. The Academic Associate and thesis advisor provide counsel in regard to courses that will stimulate individual student interest.

One free elective is offered to provide each student the opportunity to whet his intellectual appetite and stimulate growth with a course taken from any department in the school.

TWO-YEAR
M.S. (A.E.) PROGRAMS — Eight Quarters

Fourth Quarter

AE	4xxx	Specialty Course	4- 0
AE	3xxx	Elective Course	4- 0
EE	2111	Electrical Fundamentals for Aeronautical Engineers	4- 2
MA	3232	Numerical Analysis	4- 0
AE	3851	Gasdynamics Laboratory	0- 3
			16- 5

Fifth Quarter

AE	4xxx	Specialty Course	4- 0
AE	3xxx	Elective Course	4- 0
AE	4632	Computer Methods in Aeronautics	3- 2
AE	0810	Thesis Research	0- 0
			11- 2

Sixth Quarter

AE	4xxx	Elective Course	4- 0
AE	4xxx	Elective Course	4- 0
PS	3xxx	Probability and Statistics Elective	4- 0
AE	0810	Thesis Research	0- 0
			12- 0

Seventh Quarter

AE	4xxx	Elective Course	4- 0
AE	4xxx	Elective Course	4- 0
MS	2218	Elements of Engineering Materials	3- 2
AE	0810	Thesis Research	0- 0
			11- 2

Eighth Quarter

OS	3xxx	Management Elective	4- 0
OS	3xxx	Management Elective	4- 0
OS	3xxx	Management Elective	4- 0
		Free Elective	4- 0
			16- 0

THREE-YEAR

Ae. E. PROGRAMS — Eleven Quarters

Fourth Quarter

AE	4xxx	Specialty Course	4- 0
AE	3xxx	Elective Course	4- 0
EE	2111	Electrical Fundamentals for Aeronautical Engineers	4- 2
MA	3232	Numerical Analysis	4- 0
AE	3851	Gasdynamics Laboratory	0- 3
			16- 5

Fifth Quarter

AE	4xxx	Specialty Course	4- 0
AE	3xxx	Elective Course	4- 0
EE	3111	Avionics Systems	4- 2
AE	4632	Computer Methods in Aeronautics	3- 2
			15- 4

Sixth Quarter

AE	4xxx	Specialty Course	4- 0
AE	4xxx	Elective Course	4- 0
AE	4xxx	Elective Course	4- 0
PS	3xxx	Probability and Statistics Elective	4- 0
			16- 0

Seventh Quarter

AE	4xxx	Specialty Course	4- 0
AE	4xxx	Elective Course	4- 0
AE	4xxx	Elective Course	4- 0
AE	0810	Thesis Research	0- 0
			12- 0

Eighth Quarter

Experience		Tour	6 wks.
AE	0810	Thesis Research	6 wks.

Ninth Quarter

AE	4xxx	Elective	4- 0
MA	4xxx	Elective	4- 0
MS	2218	Elements of Engineering Materials	3- 2
AE	0810	Thesis Research	0- 0
			11- 2

Tenth Quarter

AE	4271	Design Problems in Aeronautics I	3- 3
AE	4xxx	Elective	4- 0
OS	3xxx	Management Elective	4- 0
AE	0810	Thesis Research	0- 0
			11- 3

Eleventh Quarter

AE	4272	Design Problems in Aeronautics II	3- 3
OS	3xxx	Management Elective	4- 0
OS	3xxx	Management Elective	4- 0
		Free Elective	4- 0
			15- 3

ONE-YEAR

M.S. (A.E.) PROGRAMS — Four Quarters

Highly qualified students recently graduated may qualify for direct entry to graduate status in the one-year program.

First Quarter

AE	4xxx	Specialty Course	4- 0
AE	3xxx	Elective Course	4- 0
MA	3232	Numerical Analysis	4- 0
MA	3xxx	Elective	4- 0
			16- 0

Second Quarter

AE	4xxx	Specialty Course	4- 0
AE	3xxx	Elective Course	4- 0
AE	4632	Computer Methods in Aeronautics	3- 2
AE	0810	Thesis Research	0- 0
			11- 2

Third Quarter

AE	4xxx	Elective Course	4- 0
AE	4xxx	Elective Course	4- 0
OS	3xxx	Management Elective	4- 0
AE	0810	Thesis Research	0- 0
			12- 0

Fourth Quarter

AE	4xxx	Elective Course	4- 0
AE	4xxx	Elective Course	4- 0
AE	0810	Thesis Research	0- 0
		Free Elective	4- 0
			12- 0

BACCALAUREATE PROGRAMS

CURRICULUM NUMBER 461

DONALD THOMAS FITZGERALD, Commander, U. S. Navy, Curricular Officer; B.S. University of Utah, 1959.

RAYMOND KENNETH HOUSTON, Academic Associate; B.S., Worcester Polytechnic Institute, 1933; M.S. 1939.

MICHAEL ANDREW ROSE, Lieutenant Commander, U. S. Navy, Assistant Curricular Officer; B.S., California Maritime Academy, 1961; B.A. with major in Government (International Relations), Naval Postgraduate School, 1970.

OBJECTIVE — To complete to the baccalaureate degree level the educational background of selected Navy officers who do not possess an accredited bachelor's degree and to prepare those officers who are capable and so motivated for graduate-level education.

QUALIFICATION FOR ADMISSION — Applicants must have an advanced undergraduate standing of at least 45 semester hours of acceptable credit, and have earned a C average in all previous college courses. Acceptable undergraduate work must include mathematics through college algebra. A minimum of 15 semester hours is required from an accredited educational institution since a maximum of 30 semester hours credit will be allowed for service schools.

DESCRIPTION — The Baccalaurate curricula provide study to complete the undergraduate education of the commissioned officer. The different educational backgrounds and personal needs of the students are accommodated by providing two basic curricula. Typical academic programs for each of these curricula are included in this section.

The Bachelor of Science curriculum emphasizes the physical environment without neglecting the social. Successful completion leads to the award of the degree Bachelor of Science in Engineering Science. As an alternative, Bachelor of Science students may specialize in one of the technical science/engineering disciplines offered at the Postgraduate School.

The Bachelor of Arts curriculum is primarily in the field of political science with specialization in government and international relations. Mathematics and physical science courses related to the professional broadening of Naval officers are included. Successful completion leads to the award of the degree Bachelor of Arts with a major in Government (International Relations).

Classes for both curricula convene in January and July. From one to two calendar years are allowed to complete the program. Students pursuing these curricula carry an average load of 16 credit hours per quarter.

BACHELOR OF ARTS WITH MAJOR IN GOVERNMENT (INTERNATIONAL RELATIONS)

First Quarter			
EN	1010	Fundamentals of Writing	4- 0
HI	2201	U.S. History 1763-1865	4- 0
GV	1060	U.S. Government	4- 0
MA	1010	Intermediate Algebra	4- 0
			16- 0
Second Quarter			
GV	2160	Comparative Government	4- 0
HI	2202	U.S. History 1865-1945	4- 0
MA	1021	College Algebra and Trigonometry	4- 0
HI	2100	European History 1815-1914	4- 0
			16- 0
Third Quarter			
GV	2161	Introduction to International Relations	4- 0
HI	2101	European History 1914-1945	4- 0
GV	2163	Western Political Thought	4- 0
PS	2000	Elementary Probability and Statistics	4- 0
			16- 0
Fourth Quarter			
GV	2164	Comparative Ideologies	4- 0
SP	1020	Public Speaking	4- 0
PH	1901	The Nature and Structure of Physics I	4- 2
LT	1040	Appreciation of Literature	4- 0
			16- 2
Fifth Quarter			
GV	2165	20th Century Social and Political Thought	4- 0
GV	2061	American National Security Policy	4- 0
MN	2030	Introduction to Economics	4- 0
PH	1902	The Nature and Structure of Physics II	4- 2
			16- 2
Sixth Quarter			
PH	1903	Physics and Modern Devices	3- 2
CS	2105	Survey of Computers and Programming	4- 0
		Electives (Government and Humanities)	8- 0
			15- 2
Seventh Quarter			
AO	2301	Aeronautical Engineering for Aviators	4- 2
AO	2302	Aviation Accident Prevention and Crash Investigation (Aviators)	3- 2
AO	2352	Psychology in Accident Prev. and Inv.	4- 0
		Electives (Government and Humanities)	4- 0
			15- 4
Eighth Quarter			
HI	2203	Continuity and Change in Recent America	4- 0
OC	2110	Introduction to Oceanography	3- 0
		Electives (Government and Humanities)	8- 0
			15- 0

BACHELOR OF SCIENCE IN ENGINEERING SCIENCE

First Quarter			
CH	1001	Introductory General Chemistry I	4- 2
MA	1021	College Algebra and Trigonometry	4- 0
GV	1060	U.S. Government	4- 0
LT	1040	Appreciation of Literature	4- 0
			16- 2

Second Quarter

CH	1002	Introductory General Chemistry II	3- 2
MA	1120	Calculus and Analytic Geometry I	5- 2
SP	1020	Public Speaking	4- 0
EN	1010	Fundamentals of Writing	4- 0
			16- 4

Third Quarter

MS	1021	Elements of Materials Science I	3- 2
MA	1121	Calculus and Analytic Geometry II	5- 2
PH	1015	Basic Physics I	5- 3
			13- 7

Fourth Quarter

MS	1022	Elements of Materials Science II	2- 2
		Elective	4- 0
PH	1016	Basic Physics II	4- 3
GV	2061	American National Security Policy	4- 0
			14- 5

Fifth Quarter

ME	2120	Elements of Engineering Thermodynamics	3- 2
PH	2017	Basic Physics III	4- 2
EE	2222	Electronic Fundamentals I	3- 2
PS	2501	Introduction to Probability and Statistics I	4- 0
			14- 6

Sixth Quarter

EE	2223	Electronic Fundamentals II	3- 3
OS	3941	Engineering Economics	4- 0
ME	2561	Statics	3- 0
CS	2100	Introduction to Computers and FORTRAN Programming	4- 0
			14- 3

Seventh Quarter

OC	2110	Introduction to Oceanography	3- 0
EE	2224	Communication and Digital Electronics	4- 3
ME	2562	Dynamics	4- 0
OS	2201	Elements of Operations Research/ Systems Analysis	4- 0
			15- 3

Eighth Quarter

AO	2302	Aviation Accident Prevention and Crash Investigation (Aviators)	3- 2
AO	2303	Aeronautical Engineering for Aviators	4- 2
AO	2352	Psychology in Accident Prev. and Inv.	4- 0
		Elective (Science and Eng./Gov't and Humanities)	4- 0
			15- 4

ELECTRONICS/COMMUNICATIONS ENGINEERING AND COMMUNICATIONS MANAGEMENT PROGRAMS

CURRICULA NUMBERS 590, 600, and 620/CG

Joe Mitchell James, Commander, U. S. Navy, Curricular Officer; B.S., Naval Academy, 1953; M.S. in Engr. Elec., Naval Postgraduate School, 1961.

Abraham Sheingold, Academic Associate; B.S., College of the City of New York, 1936; M.S. 1937.

Eugene Dexter Newton, Lieutenant Commander, U. S. Navy; Assistant Curricular Officer; B.S., University of Washington, 1961; M.S.E.E., Naval Postgraduate School, 1969.

The Electronics/Communications Engineering and Communications Management Programs include curricula designed to satisfy the needs of the service and the interest of the officers in these fields. Successful completion of a curriculum leads to the award of the degree of Master of Science, or of a higher degree in the principal field. This education permits the officer to more knowledgeably address current and future military problems associated with electronic/communication systems, and expands his base of professional knowledge and technical competence.

Within the broad field of electronics-communications engineering, various optional areas may be studied toward the attainment of a degree in electrical engineering. In the field of communications management, unique Navy and Coast Guard programs of study lead to the attainment of a degree in management. All curricula provide the officer with a well-founded comprehension of the scientific principles and technical practices in the field of study. The curricula also include studies in associated areas outside the field of specialization and in areas of particular application to the naval officer. Considerable latitude is provided to accommodate the academic background and developed interests of the officers.

ENGINEERING ELECTRONICS CURRICULUM (590)

OBJECTIVE — To provide officers, through graduate education, with comprehensive scientific and technical knowledge in the field of electronics as applied to Navy systems. This education is intended to advance the officer's professional ability in general and specifically to prepare him for duty in this subspecialty area. Upon successful completion of the curriculum, subspecialty qualification codes 8240P or 8241P will be assigned. Subspecialty billets are listed in the *Annual Naval Officer Billet Summary*.

COMMUNICATIONS ENGINEERING CURRICULUM (600)

OBJECTIVE — To provide officers, through graduate education, with a comprehensive scientific and technical knowledge in the field of communications engineering as applied to Navy and Defense Command and Control Systems. This education is intended to enhance the officer's professional ability in general and, specifically, to prepare him for duty in this subspecialty area. Upon successful completion of the curriculum, subspecialty Code 8810P will be assigned. Subspecialty billets are listed in the *Annual Naval Officer Billet Summary*.

ELECTRONIC/COMMUNICATIONS ENGINEERING

QUALIFICATIONS FOR ADMISSION — Prior baccalaureate degree, including a background and above-average grades in differential/integral calculus, and general physics. Those lacking this background may matriculate via the Engineering Science or Baccalaureate Programs.

DESCRIPTION — The 590 and 600 curricula are sponsored respectively by the Naval Electronic Systems Command/Naval Ship Systems Command and the Naval Communications Command/Naval Security Group. Classes convene in March and September. The standard curriculum duration is twenty-seven months; however, subject to approval of the parent service, the academically superior student may continue studies leading to award of the degree Engineer or Ph. D. (with major in electrical engineering). The standard curriculum presumes the officer to have a non-engineering background, except as stated in the qualifications above, and to have been absent from academic studies for four to six years. Officers who have qualifications exceeding this standard may expect to achieve advanced standing in the curriculum. Selected Naval Academy, NROTC and OCS graduates may enter directly into a graduate program (IGEP) and complete the master's degree in twelve months.

For officers who report in sufficient time, the curriculum is preceded by a non-credit, six-week refresher period which provides courses in mathematics, physics, electrical engineering and computer programming. The refresher period and the first five quarters of the standard nine-quarter curriculum are designed to provide a smooth transition from previous studies and to provide the sound undergraduate background necessary for the subsequent advanced courses and thesis research.

Early in the second year of instruction, officers are evaluated for academic progress, accomplishments, and potential to complete the remaining portion of the curriculum. Those officers who have demonstrated a capability to satisfy academic requirements for the Master of Science degree will continue in the regular curriculum and select an area of specialized study for thesis research. The officers who are unable to continue in graduate-level work will normally be scheduled to complete their studies in seven, vice nine, quarters and will receive the degree Bachelor of Science in their major field, provided academic requirements are satisfied.

STANDARD PROGRAMS — The following representative programs are designed to be academically sound, consistent with the needs of the service and the program sponsor, and responsive to interest and objectives of the individual officer.

BASIC CORE

First Quarter

MA 1100	Calculus Review	4- 0
EE 2101	Basic Circuit Theory	3- 2
MA 2045	Introduction to Linear Algebra	3- 0
PH 1041	Review of Mechanics and Electricity and Magnetism	5- 1
		15- 3

Second Quarter

CS	2100	Introduction to Computers and FORTRAN Programming	4- 0
MA	2121	Differential Equations	4- 0
EE	2102	Circuit Analysis	4- 2
EE	2211	Electronic Engineering Fundamentals I	4- 2
			16- 4

Third Quarter

MA	2172	Complex Variables	4- 0
EE	2212	Electronic Engineering Fundamentals II	4- 3
EE	2103	Linear Systems Analysis	4- 2
EE	2810	Digital Machines	3- 3
			15- 8

Fourth Quarter

EE	2621	Introduction to Fields and Waves	4- 0
PH	2241	Waves and Particles	4- 0
EE	2216	Pulse and Digital Circuits	4- 3
EE	2114	Communication Theory I	4- 0
			16- 3

Fifth Quarter

PH	2641	Atomic Physics	4- 2
EE	2217	Communication Circuits	4- 3
EE	2622	Electromagnetic Engineering	3- 1
EE	2411	Control Systems	3- 3
			14- 9

BACHELOR OF SCIENCE

Sixth Quarter

EE	3215	Microwave Devices	4- 2
EE	3631	Antennas and Propagation	3- 2
OS	3201	Fundamentals of Operations Analysis	4- 0
EE	3432	Radar Systems	3- 2
			14- 6

Seventh Quarter

EE	2311	Principles of Energy Conversion	3- 2
MN	2970	Material Management	4- 0
EE	3641	Electromagnetic Campatibility	3- 1
	xxxx	Elective	x- x

MASTER OF SCIENCE

Sixth Quarter

PS	3411	Applied Probability Theory I	4- 1
EE	3215	Microwave Devices	4- 2
EE	3631	Antennas and Propagation	3- 2
EE	4121	Advanced Network Theory I	3- 2
			14- 7

Seventh Quarter

EE	4433	Advanced Radar Systems	3- 2
EE	4571	Statistical Communication Theory	3- 2
	xxxx	Elective	x- x
EE	0810	Thesis Research	0- 0
EE	0951	Seminar	0- 1

Eighth Quarter

OS	3202	Methods of Operations Analysis/ Systems Analysis	4- 0
	xxxx	Elective	x- x
	xxxx	Elective	x- x
EE	0810	Thesis Research	0- 0
EE	0951	Seminar	0- 1

Ninth Quarter

EE	4461	Advanced Systems Engineering	3- 1
	xxxx	Elective	x- x
EE	0810	Thesis Research	0- 0
EE	0810	Thesis Research	0- 0
EE	0951	Seminar	0- 1

The officer's choice of elective courses is based on a selected option area. Listed below are representative electives associated with each option. Considerable latitude is permitted in specific elective selections, with the choices approved on the basis of general consistency with the option area, and on agreement with academic and professional requirements.

OPTION	*REPRESENTATIVE ELECTIVES*		
Advanced Electronics	PH	3741	Electronic Properties of Metals and Semi-conductors
	EE	3264	Advanced Theory of Semi-conductor Devices
	EE	3263	Integrated Circuits
	EE	3652	Microwave Circuits and Measurements
Bio Engineering	EE	3801	Human Physiology
	EE	3820	Bioelectronic Instrumentation
	OA	4680	Human Performance Evaluation
	EE	4890	Computer Modeling of Biological Systems
Computer Systems	EE	3812	Switching Theory and Logic Design
	EE	3822	Engineering Applications of Computers
	EE	4823	Advanced Digital Computer Systems
	CS	4202	Interactive Computation Systems
Communications (600) Program	EE	3422	Modern Communications
	EE	4541	Signal Processing
	EE	3822	Engineering Applications of Computers
	EE	4581	Information Theory
Information and Control	EE	4414	Stochastic Control Theory
	EE	4417	Optimal Control
	EE	4412	Nonlinear Systems
	EE	3471	Guidance and Navigation
Information Processing	EE	4581	Information Theory
	EE	4541	Signal Processing
	EE	4421	Electro-Optic Systems Engineering
	EE	3822	Engineering Applications of Computers
Electronic Warfare	EE	4481	Electronic Warfare Techniques and Systems
	EE	4482	SIGINT Systems Engineering
	EE	4421	Electro-Optics Systems Engineering
	EE	3471	Guidance and Navigation

ELECTRICAL ENGINEER

As determined by superior academic achievement, officers may matriculate into a program leading to the advanced degree, Electrical Engineer. This advanced graduate program requires seven quarters of work be-

yond the Basic Core. The scope of study is greatly increased over the Master of Science curriculum and a thesis of greater depth is required. In addition, the officer is provided an opportunity for an Industrial Experience Tour of up to 12 weeks' duration.

COMMUNICATIONS MANAGEMENT CURRICULUM (620/620CG)

OBJECTIVE — To provide instruction to officers who will perform as Communications Managers of communications systems or as Communications Officers in large commands and staffs, afloat and ashore, including the Naval Communications Command, the Joint Chiefs of Staff and the Defense Communications Agency. Upon successful completion of the curriculum, subspecialty qualification code 8801P will be assigned. Subspecialty billets are listed in the *Annual Naval Officer Billet Summary.*

DESCRIPTION — The 620 and 620CG Curricula are sponsored respectively by the Naval Communications Command and the U. S. Coast Guard Headquarters. Each curriculum provides comprehensive study in management, with emphasis upon the systems management field. Additionally, the curricula provide study in the technical field appropriate to decision making in advanced system and program management. These technical courses within the 620 curriculum have been especially prepared for non-engineers, whereas those in the 620CG curriculum are engineering courses.

The 620 classes convene in March and September, and the 620CG classes in September. The duration of the 620 curriculum is 18 months, and the 620CG curriculum is 24 months. For officers arriving sufficiently in advance of the convening dates, the curricula are preceded by a non-credit six-week refresher period which provides courses in mathematics, computer programming and physics.

QUALIFICATIONS FOR ADMISSION TO COMMUNICATIONS MANAGEMENT — Admission to the curricula requires a baccalaureate degree with average grades. Completion of mathematics through college algebra and trigonometry is required for the 620 curriculum. The student must be ready to start calculus courses on enrollment. The qualifications for the 620CG curriculum are the same as the 590 and 600 curricula.

STANDARD PROGRAMS — The following representative programs are designed to be academically sound, consistent with the needs of the service and the program sponsor, and responsive to the interests and objectives of the individual officer.

COMMUNICATIONS MANAGEMENT (620)

First Quarter

CO	2111	Defense Communications Organization and Planning	4- 0
MA	1120	Calculus and Analytic Geometry I	5- 2
CS	2100	Introduction to Computers and FORTRAN Programming	4- 0
MN	3150	Financial Accounting	4- 0
			17- 2

Second Quarter

PS	3000	Management Statistics	5- 0
MA	1121	Calculus and Analytic Geometry II	5- 2
CO	2112	Defense Communications Systems	3- 2
EE	2421	Introduction to Communications Technology	4- 2
			17- 6

Third Quarter

MN	3106	Behavioral Science	4- 0
MN	3140	Microeconomic Theory	4- 0
MN	3211	Operations Analysis for Management I	3- 2
EE	2422	Communications Systems I	4- 3
			15- 5

Fourth Quarter

MN	3105	The Theory and Practice of Management	4- 0
EE	2423	Communications Systems II	4- 3
MN	3170	Defense Resource Allocation	4- 0
EE	2424	Signal Transmission Systems	4- 2
			16- 5

Fifth Quarter

EE	3425	Communication System Analysis	3- 3
MN	4171	Procurement and Contract Administration	4- 0
MN	3183	Management Use of Computers	4- 0
CM	0810	Thesis Research	0- 0
CM	0001	Seminar	0- 2
			11- 5

Sixth Quarter

CM	0810	Thesis Research	0- 0
	xxxx	Elective	x- x
	xxxx	Elective	x- x
CT	4182	Data Processing Management	4- 0
CM	0001	Seminar	0- 2

COMMUNICATIONS MANAGEMENT (620CG)

First Quarter

MN	3106	Behavioral Science	4- 0
MN	3141	Microeconomics	4- 0
MN	3150	Financial Accounting	4- 0
CS	2100	Introduction to Computers and FORTRAN Programming	4- 0
			16- 0

Second Quarter

EE	2101	Basic Circuit Theory	3- 2
MA	2045	Introduction to Linear Algebra	3- 0
MN	3105	The Theory and Practice of Management	4- 0
MA	1100	Calculus Review	4- 0
			14- 2

Third Quarter

EE	2221	Electronic Engineering Fundamentals I	4- 2
EE	2102	Circuit Analysis	4- 2
MA	2121	Differential Equations	4- 0
CS	3200	Structure of Digital Computers	4- 0
			16- 4

Fourth Quarter

EE	2212	Electronic Engineering Fundamentals II	4- 3
EE	2103	Linear Systems Analysis	4- 2
MA	2172	Complex Variables	4- 0
PS	3411	Applied Probability Theory I	4- 1
			16- 6

Fifth Quarter

EE	2114	Communication Theory I	4- 0
EE	2216	Pulse and Digital Circuits	4- 3
EE	2621	Introduction to Fields and Waves	4- 0
MN	3183	Management Use of Computers	4- 0
			16- 3

Sixth Quarter

EE	2622	Electromagnetic Engineering	3- 1
MN	4181	Management Information Systems	4- 0
CT	4182	Data Processing Management	4- 0
EE	4571	Statistical Communication Theory	3- 2
			14- 3

Seventh Quarter

EE	3422	Modern Communications	3- 2
MN	3170	Defense Resources Allocation	4- 0
OS	3203	Survey of Operations Analysis/ Systems Analysis	4- 0
MN	xxxx	Elective	4- 0
			15- 2

Eighth Quarter

MN	4171	Procurement and Contract Administration	4- 0
EE	3631	Antennas and Propagation	3- 2
OA	4633	Network Flows and Graphs	4- 0
MN	xxxx	Elective	x- x

REPRESENTATIVE ELECTIVES

The officer's choice of electives is approved on the basis of consistence with the curriculum and academic and professional requirements. Below are a few courses representative of the many from which selection may be made:

MN	4105	Management Policy
MN	3121	Group and Organizational Behavior
MN	4145	Systems Analysis
MN	3161	Managerial Accounting
MN	4175	Rhochrematics

Main entrance to the Naval Postgraduate School showing the Dudley Knox Library which opened its doors for business in January 1972

ENGINEERING SCIENCE PROGRAMS
CURRICULUM NUMBER 460

PHILIP JOHN O'CONNELL JR., Lieutenant Commander, U. S. Navy; Curricular Officer; B.S., Naval Academy, 1959; B.S.M.E., Naval Postgraduate School, 1967.

ELMO JOSEPH STEWART, Academic Associate; B.S., University of Utah, 1937; M.S., 1939; Ph.D., Rice Institute, 1953.

OBJECTIVE —
a. Refresh officer students with previous study in undergraduate mathematics and physical science for six months in preparation for admission into an advanced technical program.
b. Provide officer students having little or no undergraduate mathematics and physical science study with an opportunity to establish a good foundation in these areas over a period of six to twelve months, and thus qualify them for admission into an advanced technical program.

QUALIFICATIONS FOR ADMISSION — A baccalaureate degree and successful completion of at least one college mathematics course in algebra or trigonometry.

DESCRIPTION — There are two annual inputs to the Engineering Science Programs, one in March, the other in September. After successfully completing sit months in Engineering Science, almost all officers transfer into an advanced technical curriculum. Acceptance by another curriculum depends upon the number of available quotas in that curriculum and the student's academic performance. The academic performance demonstrated in Engineering Science greatly influences the decision with respect to the student's academic ability, regardless of previous scholastic achievement.

To adapt the Engineering Science curriculum to the varied backgrounds and interests presented by the officer students, six basic programs are available to each input:

(1) SA — Course sequence in preparation for Operations Research/Systems Analysis, and Computer Science. Also used for officers with a good physical science and mathematics background who have not chosen a graduate curriculum.
(2) SB — Course sequence in preparation for Aeronautical Engineering or Naval Engineering.
(3) SC — Course sequence in preparation for Ordnance Engineering, Engineering Electronics, Communications Engineering.
(4) SD — Course sequence in preparation for Environmental Sciences.
(5) SE — For those officers with a fair physical science and mathematics background.
(6) SF — For those officers with a weak physical science and mathematics background.

Additional factors that affect the placement of an officer in one of these programs are: undergraduate courses and grades achieved; undergraduate institution; length of time away from formal academic study; and, when feasible, the officer's personal desires.

During his first quarter, each Engineering Science officer student attends a series of lectures given by the curricular officers of other programs in which the details of their respective curricula are presented. In this way, the new officer student is exposed to every technical program which is available to him at the Naval Postgraduate School.

No degree or subspecialty qualification results from successful completion of an Engineering Science program.

The Engineering Science curriculum provides a beneficial six-month academic warmup to every officer student who desires advanced technical training. This same officer enjoys the advantage of selecting an advanced technical program after attending the Engineering Science lectures series and being exposed to all the Naval Postgraduate School programs available to him. The terminal officer student receives a one-year education during which his undergraduate education in mathematics and physical sciences has been broadened and updated. By virtue of this improved educational foundation, the terminal student has improved his ability to understand and cope with the scientific environment of whch he is a part. This can only enhance his value and future professional performance as an officer.

The courses listed in each program are those recommended to improve an officer's opportunity for a technical curriculum. Substitutions may be made for the third and fourth courses in each respective quarter to complement undergraduate work. Course substitutions will depend on the officer's academic background and the availability of the course desired. Allied officers are requested to take American Life and Institutions, GV 1368, (3-0), in place of a scheduled course during the first quarter.

GROUP SA

First Quarter

MA	1115	Calculus I	5- 0
PH	1011	Basic Physics I	4- 0
CS	2100	Introduction to Computers and FORTRAN Programming	4- 0
MA	2025	Logic, Sets and Finite Mathematics	4- 0
			17- 0

Second Quarter

MA	1116	Calculus II	5- 0
MA	2045	Introduction to Linear Algebra	3- 0
PS	2501	Introduction to Probability and Statistics I	4- 0
OA	2201	Elements of Operations Research/ Systems Analysis	4- 0
			16- 0

GROUP SB

First Quarter

MA	1115	Calculus I	5- 0
PH	1011	Basic Physics I	4- 0
CS	2100	Introduction to Computers and FORTRAN Programming	4- 0
ME	2561	Statics	3- 0
			16- 0

Second Quarter

MA 1116	Calculus II	5- 0
PH 1012	Basic Physics II	4- 0
MA 2045	Linear Algebra	3- 0
ME 2562	Dynamics	4- 0
		16- 0

GROUP SC

First Quarter

MA 1115	Calculus I	5- 0
PH 1011	Basic Physics I	4- 0
CS 2100	Introduction to Computers and FORTRAN Programming	4- 0
MA 2025	Logic, Sets and Finite Mathematics	4- 0
		17- 0

Second Quarter

MA 1116	Calculus II	5- 0
PH 1012	Basic Physics II	4- 0
PS 2501	Introduction to Probability and Statistics I	4- 0
EE 2421	Introduction to Communications Technology	4- 2
		17- 2

GROUP SD

First Quarter

MA 1115	Calculus I	5- 0
PH 1011	Basic Physics I	4- 0
CS 2100	Introduction to Computers and FORTRAN Programming	4- 0
OC 2110	Introduction to Oceanography	3- 0
		16- 0

Second Quarter

MA 1116	Calculus	5- 0
PH 1012	Basic Physics II	4- 0
PS 2501	Introduction to Probability and Statistics I	4- 0
MR 2100	Survey of Meteorology	3- 0
		16- 0

GROUP SE

First Quarter

MA 1120	Calculus and Analytic Geometry I	5- 2
PH 1011	Basic Physics I	4- 0
CS 2100	Introduction to Computers and FORTRAN Programming	4- 0
OC 2110	Introduction to Oceanography	3- 0
		16- 2

Second Quarter

MA 1121	Calculus and Analytic Geometry II	5- 2
PH 1012	Basic Physics II	4- 0
PS 2501	Introduction to Probability and Statistics I	4- 0
	Elective	4- 0
		17- 2

GROUP SF

First Quarter

MA 1021	College Algebra and Trigonometry	4- 0
PH 1005	Elementary Physics I	4- 2
CH 1001	Introductory General Chemistry I	4- 2
OC 2110	Introduction to Oceanography	3- 0
		15- 4

Second Quarter

MA 1120	Calculus and Analytical Geometry I	5- 2
PH 1006	Elementary Physics II	3- 2
EE 2221	Basic Communications Technology	4- 2
CS 2100	Introduction to Computers and FORTRAN Programming	4- 0
		16- 6

ENVIRONMENTAL SCIENCES PROGRAMS
CURRICULA NUMBERS 372 and 440

JAMES JOSEPH DAGDIGIAN, Commander, U. S. Navy; Curricular Officer, B.S., Massachusetts Maritime Academy, 1953; B.S. in Meteorology, Naval Postgraduate School, 1962.

CHARLES LUTHER TAYLOR, Academic Associate (Meteorology); B.S., Pennsylvania State University, 1942; M.S., 1947.

JOSEPH JOHN VON SCHWIND, Academic Associate (Oceanography); B.S., University of Wisconsin, 1952; M.S., University of Utah, 1960; Ph.D., Texas Agricultural and Mechanical University, 1968.

CHARLES HOWARD BASSETT, JR., Commander, U. S. Navy; Assistant Curricular Officer; B.S., West Virginia University, 1956; M.S., Naval Postgraduate School, 1965.

OBJECTIVE — To provide advanced education in meteorology and oceanography to meet the Navy's operational and technical requirements in the environmental sciences.

QUALIFICATIONS FOR ADMISSION — Admission to curricula in the environmental sciences requires a baccalaureate degree with above-average grades in mathematics and the physical sciences. Completion of mathematics through differential and integral calculus and one year of college physics is considered to be minimal preparation. The Oceanography Curriculum additionally requires one year of college chemistry.

The baccalaureate degree and mathematics requirement are waived for admission to the General Meteorology Curriculum provided mathematics prerequisite to calculus has been completed.

DESCRIPTION — Curriculum number 372 consists of an eight-quarter program in Advanced Meteorology leading to the attainment of the degree of Master of Science in Meteorology. Matriculation is scheduled for quarters beginning in September and March. Six-week refresher courses in calculus, physics, and computer programming are available prior to commencing the first quarter, and attendance is highly recommended.

The Meteorology Curriculum, number 372, consists basically of core sequences of courses in dynamic, synoptic, and physical meteorology. Sufficient practical laboratory work and oceanographic courses are included to prepare officers to become qualified operational meteorologists with a working knowledge of oceanography. Numerical methods are emphasized, and the Advanced Meteorology Curriculum prepares officers to conduct independent scientific research. Upon completion of the curriculum, unrestricted line officers are assigned a subspecialty qualification code of 8610P.

The Oceanography Curriculum, number 440, is of eight quarters' duration, and classes convene in September and March. The program provides a broad basic education in oceanography, including courses in biological, geological, and chemical oceanography. In addition, ample courses in meteorology are provided to give the student an understanding of the marine environment and the air-sea interaction relationships. The core of the curriculum is, however, the sequence of courses in physical oceanography. Emphasis is placed upon the application of oceanography to naval operations, particularly in the field of antisubmarine warfare, and practical experience in the use of oceanographic instruments and the collection of scientific observations at sea are included. As in meteorology, computer technology is emphasized and officers are prepared to conduct independent research.

A Master of Science in Oceanography degree is awarded upon completion of the curriculum, provided the general requirements for the master of science degree are met. Unrestricted line officers completing the Oceanography Curriculum, number 440, will be assigned a subspecialty qualification code 8710P.

Certain conditions are applicable to both the Meteorology and Oceanography Curricula. Both programs have common courses during the first three quarters and, in some cases, students in Oceanography and Meteorology will attend the same classes. Both programs require the completion of an acceptable thesis in the area of the major. Individuals with suitable qualifications may request approval for modified programs to build competence in particular aspects of their chosen area of studies.

Selected Naval Academy, NROTC, and OCS graduates may enter directly into a graduate program (IGEP) in either Meteorology or Oceanography, and obtain a master's degree upon completion of four quarters course work, including an acceptable thesis.

ADVANCED METEOROLOGY CURRICULUM
CURRICULUM NUMBER 372

First Quarter			
MR	0110	Faculty Seminar	1- 0
MA	2047	Linear Algebra and Vector Analysis	4- 0
MA	2121	Differential Equations	4- 0
MR	2200	Introduction to Meteorology	4- 0
MR	2205	Introduction to Meteorological Analysis	0- 4
OC	2120	Survey of Oceanography	4- 0
			17- 4
Second Quarter			
MR	2520	Climatology and Statistics	3- 0
MR	2420	Principles of Measurement	3- 2
MR	3420	Geophysical Thermodynamics	4- 0
MA	3232	Numerical Analysis	4- 0
MA	3132	Partial Differential Equations and Integral Transforms	4- 0
			18- 2
Third Quarter			
OC	3150	Geophysical Random Processes	3- 1
MR	4412	Heat Transfer Processes	4- 0
MR	4321	Introductory Geophysical Fluid Dynamics	4- 0
MR	3220	Meteorological Analysis	3- 0
MR	3225	Meteorological Analysis Laboratory	0- 6
			14- 7

Fourth Quarter

MR 3230	Tropospheric and Stratospheric Meteorology	4- 0
MR 3235	Tropospheric and Stratospheric Meteorology Laboratory	0- 9
MR 4322	Dynamic Meteorology	4- 0
MA 3243	Numerical Methods for Partial Differential Equations	4- 1
		12-10

Fifth Quarter

MR 4413	Air/Sea Interaction	4- 0
MR 3250	Tropical and Southern Hemisphere Meteorology	3- 0
MR 3255	Tropical and Southern Hemisphere Meteorology Laboratory	0- 6
MR 4323	Numerical Weather Prediction	4- 3
		11- 9

Sixth Quarter

OC 3260	Sound in the Ocean	3- 0
MR 3260	Prognostic Charts and Extended Forecasting	3- 0
MR 3265	Prognostic Charts and Extended Forecasting Laboratory	0- 6
*MR 4xxx	(Elective)	3- 0
MR 0810	Thesis Research	0- 0
		9- 6

Seventh Quarter

MR 3421	Cloud Physics and Atmospheric Pollution	3- 1
OC 3611	Ocean Wave and Surf Forecasting	2- 0
OC 3615	Ocean Wave and Surf Forecasting Laboratory	0- 4
MR 0810	Thesis Research	0- 0
		5- 5

Eighth Quarter

OC 3616	Acoustical Forecasting	3- 0
OC 3621	Acoustical Forecasting Laboratory	0- 4
MR 4900	Seminar in Meteorology	2- 0
OC 3279	Case Studies in Environmental Support	0- 4
MR 0810	Thesis Research	0- 0
		5- 8
MR 4240	Advanced Atmospheric Analysis	3- 0
MR 4415	Atmospheric Turbulence	3- 0
MR 4800	Advanced Topics in Analysis and Prediction	3- 0

Or oceanography, hydrodynamics, or mathematics courses.

**Electives*

PHYSICAL OCEANOGRAPHY CURRICULUM
CURRICULUM NUMBER 440

First Quarter

OC 0110	Faculty Seminar	1- 0
MA 2047	Linear Algebra and Vector Analysis	4- 0
MR 2200	Introduction to Meteorology	4- 0
MR 2205	Introduction to Meteorological Analysis	0- 4
OC 2120	Survey of Oceanography	4- 0
MA 2121	Differential Equations	4- 0
		17- 4

Second Quarter

MR 2520	Climatology and Statistics	3- 0
MR 2420	Principles of Measurement	3- 2
MR 3420	Geophysical Thermodynamics	4- 0
MA 3232	Numerical Analysis	4- 0
MA 3132	Partial Differential Equations and Integral Transforms	4- 0
		18- 2

Third Quarter

OC 3150	Geophysical Random Processes	3- 1
OC 3221	Descriptive Physical Oceanography	4- 0
MR 4321	Introductory Geophysical Fluid Dynamics	4- 0
MR 3220	Meteorological Analysis	3- 0
MR 3225	Meteorological Analysis Laboratory	0- 6
		14- 7

Fourth Quarter

OC 3320	Geological Oceanography	3- 3
OC 4322	Ocean Circulation	4- 0
MR 3240	Weather Elements	4- 0
MR 3245	Weather Elements Forecasting	0- 6
		11- 9

Fifth Quarter

OC 3420	Biological Oceanography	3- 3
OC 3709	Scientific Cruise Experience	0- 4
MR 4413	Air/Sea Interaction	3- 0
OC 4211	Waves and Tides	4- 0
PH 3431	Physics of Sound in the Ocean	3- 0
		13- 7

Sixth Quarter

*OC 3710	Oceanographic Cruise Planning and Field Experience	2- 4
*OC 4612	Polar Oceanography	3- 2
OC 3520	Chemical Oceanography	3- 2
OC 4260	Sound in the Ocean	3- 0
OC 0810	Thesis Research	0- 0
		8- 6 or 9- 4

Seventh Quarter

OC 4213	Coastal Oceanography	3- 1
OC 4601	Ocean Wave Forecasting	3- 0
OC 3605	Ocean Wave Forecasting Laboratory	0- 4
OC 0810	Thesis Research	0- 0
		6- 5

Eighth Quarter

OC 3616	Acoustical Forecasting	3- 0
OC 3621	Acoustical Forecasting Laboratory	0- 4
OC 3279	Case Studies in Environmental Support	0- 4
OC 4900	Seminar in Oceanography	2- 0
OC 0810	Thesis Research	0- 0
		5- 8

**Students will elect either OC 3710 or OC 4612*

MANAGEMENT AND COMPUTER SCIENCE PROGRAMS

CURRICULA NUMBERS 367, 368, 814, 816 and 817

WINDOM LAWRENCE ESTES, Commander, U. S. Navy; Curricular Officer; B.S. with major in Mathematics, Naval Postgraduate School, 1963, M.S., in Computer Science, 1970.

UNO ROBERT KODRES, Academic Associate for Computer Science and Computer Systems Management; B.A. Wartburg College, 1954; M.S. Iowa State University, 1956; Ph.D., 1958.

RICHARD SANFORD ELSTER, Academic Associate for Management and Systems Acquisition Management; B.A., University of Minnesota, 1963; M.A., 1965; Ph.D., 1967.

THOMAS FRANCIS O'NEILL, JR., Commander, U. S. Navy; Assistant Curricular Officer; B.S., Naval Academy, 1950; M.A. in Public Administration, University of Oklahoma, 1972.

COMPUTER SYSTEMS MANAGEMENT CURRICULUM CURRICULUM NUMBER 367 (GROUP CT)

OBJECTIVE — To provide officers with a sound understanding of computer technology, enabling them to distinguish the capabilities and limitations of digital computers in various applications and to develop the ability to effectively manage computer-based activities or data processing centers afloat or ashore.

QUALIFICATIONS FOR ADMISSION — A baccalaureate degree with above-average grades in mathematics is required. Completion of two semesters of college mathematics, at or above, the level of college algebra is considered to be minimal preparation for Supply Corps Officers. For Navy Line Officers the completion of differential and integral calculus is required.

DESCRIPTION — The curriculum consists of five academic quarters (15 months). Classes convene semiannually in March and September. To satisfy the requirements of sponsoring activities, students may select five elective courses as indicated in order to pursue their special areas of interest. For line officers, courses are provided which emphasize the technical areas of programming, the use of computers, and quantitative decision-making techniques. For Supply officers, courses are provided in the areas of procurement, logistics, and financial management.

Students in this curriculum are afforded the opportunity to qualify for the degree of Master of Science in Computer Systems Management. All Naval officers successfully completing the program are considered qualified to fill any billet in the 9210 series.

First Quarter

MA	2300	Mathematics for Management	5- 0
CS	2103	Introduction to Computers and COBOL Programming	4- 0
MN	3106	Behavioral Science	4- 0
MN	3150	Financial Accounting	4- 0
CT	0001	Seminar	0- 2
			17- 2

In addition, those students with no prior computer programming experience will be enrolled in CS0110 if not completed during the refresher period.

Second Quarter

CS	3111	Fundamental Concepts in Structural Programming Languages	4- 0
CS	3200	Structure of Digital Computers	4- 0
PS	3011	Probability and Statistics for Management I	4- 0
MN	3141	Microeconomics	4- 0
CT	0001	Seminar	0- 2
			16- 2

Third Quarter

CS	3112	Operating Systems	4- 0
PS	3012	Probability and Statistics for Management II	4- 0
MN	3105	Theory and Practice of Management	4- 0
CT	0001	Seminar	0- 2
		Elective (3000/4000 level CS, MN, or OA Course)	4- 0
			16- 2

Fourth Quarter

MN	3211	Operations Analysis for Management I	4- 0
MN	3170	Defense Resource Allocation	4- 0
		Elective (3000/4000 level CS, MN, or OA Course)	4- 0
		Elective (3000/4000 level CS, MN, or OA Course)	4- 0
CT	0001	Seminar	0- 2
			16- 2

Fifth Quarter

MN	4181	Management Information Systems	4- 0
CT	4182	Data Processing Management	4- 0
		Elective (4000 level CS, MN, or OA Course)	4- 0
		Elective (4000 level CS, MN, or OA Course)	4- 0
CT	0001	Seminar	0- 2
			16- 2

Note: *A thesis may be undertaken in the Fourth and Fifth Quarters in lieu of one elective in each of these quarters.*

COMPUTER SCIENCE CURRICULUM CURRICULUM NUMBER 368 (GROUP CS)

OBJECTIVE — To provide selected officers with an advanced education in computer science in order that they will have a sound technical appreciation of computer theory and technology with the ability to specify, design, and manage computer-based systems.

QUALIFICATIONS FOR ADMISSION — A baccalaureate degree with a pattern of above-average grades in mathematics is required. Completion of mathematics through differential and integral calculus is considered minimal preparation. Courses affording a background in physical science or engineering fields are highly desirable.

DESCRIPTION — A relatively new academic discipline, computer science is concerned with the representation, storage and manipulation of information by techniques and devices applicable to a wide

variety of problems. This program is designed to help fulfill the Navy's rapidly expanding needs in the field of automatic data processing, both of an operational and supporting nature.

Classes convene annually in September. All students take a common curriculum for the first nine months (three quarters). Those officers selected for the master's program continue for an additional year of study (for a total of seven quarters, overall) and are afforded the opportunity to qualify for the degree of Master of Science in Computer Science. This selection is based on the student's academic performance, his preference, and availability. Officers not selected for the master's program complete one final quarter in the bachelor's program (four quarters overall) and upon successful completion, are awarded the degree of Bachelor of Science with major in Computer Science. Selected Naval Academy, NROTC, and OCS graduates may enter directly into a graduate program (IGEP) and obtain a master's degree upon completion of four-quarters course work, including an acceptable thesis.

This program involves course work in computer science supported by instruction in mathematics, probability and statistics, operations analysis, and management. In computer science, the emphasis is on programming systems and systems design, particularly those aspects of the theory of relevance to military applications. The master's program permits further specialization by way of elective courses. The student will acquire significant practical experience on the excellent equipment of the Postgraduate School's Computer Facility. Most of the later courses, and, it is expected, the thesis, will involve heavy use of computers.

All Naval officers successfully completing either the seven-quarter master's program or four-quarter bachelor's program are considered qualified to fill any billet in the 9220 series, Computer Science.

The normal program followed by students enrolled in the Computer Science curriculum is as follows:

First Quarter

CS	2110	Introduction to Computers and Programming	3- 2
MA	1100	Calculus Review	4- 0
MA	2025	Logic, Sets, and Finite Mathematics	4- 0
MA	2045	Introduction to Linear Algebra	3- 0
CS	0001	Seminar	0- 1
			14- 3

In addition, those students with no prior computer programming experience will be enrolled in CS 0110 if not completed during the refresher period.

Second Quarter

CS	3111	Fundamental Concepts in Structural Programming Languages	4- 0
CS	3200	Structure of Digital Computers	4- 0
MA	2121	Differential Equations	4- 0
PS	3401	Intermediate Probability and Statistics I	4- 0
CS	0001	Seminar	0- 1
			16- 1

Third Quarter

CS	3112	Operating Systems	4- 0
PS	3402	Intermediate Probability and Statistics II	4- 0
MA	3232	Numerical Analysis	4- 0
MA	3026	Topics in Discrete Mathematics	4- 0
CS	0001	Seminar	0- 1
			16- 1

Fourth Quarter

CS	3300	Information Structures	3- 0
CS	3601	Automata and Formal Languages	3- 0
CS	4202	Interactive Computation Systems	3- 2
OA	3653	Systems Simulation	4- 0
CS	0001	Seminar	0- 1
			13- 3

Fifth Quarter

CS	4113	Compiler Design and Implementation	3- 2
CS	3201	Computer Systems	4- 0
CS	4310	Non-numerical Information Processing	4- 0
OS	3205	Operations Research for Computer Scientists	4- 0
CS	0001	Seminar	0- 1
			15- 3

Sixth Quarter

CS	3204	Data Communications	4- 0
CS	4900	Advanced Topics in Computer Science	4- 0
CS	0810	Thesis Research	0- 0
CS	0001	Seminar	0- 1
			8- 1

Seventh Quarter

CT	4182	Data Processing Management	4- 0
		Elective (CS, EE, MA, OA, MN)	3 or 4- 0
CS	0810	Thesis Research	0- 0
CS	0001	Seminar	0- 1
			7 or 8- 1

SYSTEMS ACQUISITION MANAGEMENT CURRICULUM CURRICULUM NUMBER 816 (GROUP SM)

OBJECTIVE — To provide selected officers with an advanced education in the fundamental concepts, methodology, and analytical techniques required for the life cycle management of planning and acquisition of defense systems.

QUALIFICATION FOR ADMISSION — A baccalaureate degree with above-average grades is required. Completion of differential and integral calculus is considered minimal mathematical preparation. Courses affording a background in engineering or physical science, and in the use of computers, are highly desirable. Officers whose undergraduate records do not meet the requirements may be accepted, if their aptitude is demonstrated by other indicators of success, such as experience, professionalism, Graduate Record Examination scores, and outstanding motivation for the program. When such officers are admitted to the curriculum their specific academic deficiencies must be removed prior to enrolling in the curriculum. Those admitted to the curriculum with complete academic qualifications, but without recent formal academic or professional usage of their undergraduate major and the above required mathematics,

should exert every effort to attend the Refresher Course offered immediately prior to the convening of the curriculum.

DESCRIPTION — The curriculum is of six quarters' (18 month) duration, convening semiannually in March and September. This program is designed to fulfill the Navy's expanding needs for project management personnel to staff designated program offices, SUPSHIP, NAVPRO, and related activities having systems acquisition management responsibilities.

In addition to basic "core" courses, which provide the foundations and tools for project management, students take specialized courses dealing with the systems acquisition discipline.

Classroom instruction includes lectures, case studies, problem exercises, and seminars. These afford the student the opportunity to participate in a project environment and to hear discussions of systems acquisition management topics presented by senior Naval officers and program managers.

Individual or group theses, including the simulation of a project office, focus the courses taken into the solution of a significant program exercise as a culminating experience.

Successful completion of the program leads to the award of the degree of Master of Science in Management with a P-Code in Systems Acquisition Management.

The normal program followed by students enrolled in the Systems Acquisition Management curriculum is as follows:

First Quarter

SM	3301	Introduction to Systems Acquisition	4- 0
MN	3150	Financial Accounting	4- 0
SM	3302	Fundamentals of Project Management	4- 0
OS	3201	Fundamentals of Operations Analysis	4- 0
SM	0001	Seminar	0- 2
			16- 2

In addition, those students with no prior computer programming experience will be enrolled in CS 1010 if not completed during the refresher period.

Second Quarter

MN	3141	Microeconomics	4- 0
MN	3161	Managerial Accounting	4- 0
SM	3304	The Behavioral Sciences and Project Management	4- 0
OS	3202	Methods of Operations Analysis/ Systems Analysis	4- 0
SM	0001	Seminar	0- 2
			16- 2

Third Quarter

MN	4145	Systems Analysis	4- 0
OS	3203	Survey of Operations Analysis/ Systems Analysis	4- 0
SM	3305	Project Information Systems	4- 0
OA	4662	Reliability and Weapons System Effectiveness Measurement	4- 0
SM	0001	Seminar	0- 2
			16- 2

Fourth Quarter

SM	4303	Procurement Planning and Negotiation	4- 0
SM	4302	Public Expenditure, Policy and Analysis	4- 0
SM	4301	Systems Engineering Management	4- 0
SM	0810	Thesis Research	0- 0
SM	0001	Seminar	0- 2
			12- 2

Fifth Quarter

SM	4304	Contract Administration	4- 0
MN	4101	Personnel Management and Labor Relations	4- 0
SM	4305	Logistics Support	4- 0
SM	0810	Thesis Research	0- 0
SM	0001	Seminar	0- 2
			12- 2

Sixth Quarter

MN	4172	Marketing Strategy	4- 0
		Elective	4- 0
		Elective	4- 0
SM	0810	Thesis Research	0- 0
SM	0001	Seminar	0- 2
			12- 2

MANAGEMENT CURRICULUM
CURRICULA NUMBERS 814 and 817
(GROUP MN)

OBJECTIVE — To provide officers with increased education in Management which will improve their capabilities for planning, organizing, directing, coordinating and controlling activities in which the resources of men, money, and materials are combined to accomplish Navy objectives.

QUALIFICATIONS FOR ADMISSION — A baccalaureate degree with over-all academic performance of at least C+ is required. Completion of two semesters of college mathematics at, or above the level of college algebra, and a C average in all quantitative courses is considered to be minimal preparation. Courses in differential and integral calculus are very desirable. Officers admitted to the curriculum with complete academic qualifications, but without recent formal academic or professional usage of their undergraduate major and the above mathematics, should exert every effort to attend the refresher course immediately prior to curriculum commencement.

DESCRIPTION — The curriculum is of twelve months' duration, convening semiannually in January and July. All officers, regardless of designator, are required to undertake the "core" curriculum. This curriculum provides the foundation and tools of management and leads into the electives which permit specialization in fields of interest to sponsoring bureaus and agencies. Areas of specialization currently available include personnel management, financial management, material management, management science, and economics.

Classroom instruction is supplemented by a guest lecturer series which affords the officer an opportunity to hear discussions of management topics by senior military officers, business executives, and prominent educators.

Successful completion of the Management curriculum leads to the degree of Master of Science in Management. Educational achievement codes, appropriate to the area of specialization, are assigned to graduates by the Chief of Naval Operations. Naval officers completing the program are considered qualified to fill appropriate billets in the 9XXX series, Management.

The core curriculum followed by students enrolled in Management is as follows:

First Quarter

MA 2300	Mathematics for Management	5- 0
MN 3141	Microeconomics	4- 0
MN 3150	Financial Accounting	4- 0
MN 3106	Behavioral Science	4- 0
MN 0001	Seminar	0- 2
		17- 2

In addition, those students with no prior computer programming experience will be enrolled n CS 0110 if not completed during the refresher period.

Second Quarter

PS 3000	Management Statistics	5- 0
MN 3105	Theory and Practice of Management	4- 0
MN 3161	Managerial Accounting	4- 0
MN 4145	Systems Analysis	4- 0
MN 0001	Seminar	0- 2
		17- 2

Third Quarter

MN 3211	Operations Analysis for Management I	4- 0
MN 3183	Management Uses of Computers	4- 0
	Elective (30000/4000 level, in area of specialization)	4- 0
	Elective (30000/4000 level, in area of specialization)	4- 0
MN 0001	Seminar	0- 2
		16- 2

Fourth Quarter

MN 4105	Management Policy	4- 0
	Elective (3000/4000 level, in area of specialization)	4- 0
	Elective (3000/4000 level, in area of specialization)	4- 0
	Elective (3000/4000 level)	4- 0
MN 0001	Seminar	0- 2
		16- 2

Note: *A thesis may be undertaken in the third and fourth quarters in lieu of one elective in each of these quarters.*

Two of the six boats available to members of the Postgraduate School Sailing Association

NAVAL ENGINEERING PROGRAMS
CURRICULUM NUMBER 570

PHILIP FURST CAROTHERS, JR., Commander, U. S. Navy; Curricular Officer; B.S.M.E., Pennsylvania State University, 1952; M.S.M.E., Naval Postgraduate School, 1961.

ROY WALTERS PROWELL, Academic Associate; B.S. in I.E., Lehigh University, 1936; M.S.M.E., University of Pittsburgh, 1943.

OBJECTIVE — To provide selected Naval officers, irrespective of designator, advanced education using the particularly appropriate vehicles of the mechanical or electrical engineering disciplines to develop the capability for independent and creative problem solving in the entire spectrum of future duty assignments be they at sea in one of the modern, technically sophisticated warships or in the demanding business of the Navy ashore (with particular emphasis on shore assignments within the Naval Material Command).

QUALIFICATIONS FOR ADMISSION — To qualify for admission to the Naval Engineering Programs, a baccalaureate degree with above-average grades in mathematics, physical sciences, and engineering is required. Completion of mathematics through integral calculus, engineering physics, and chemistry is considered to be minimal preparation for these programs. Courses in statics, dynamics, fluid mechanics, thermodynamics, electric fields, electric circuits, and electronics are desirable.

DESCRIPTION — Qualified students normally enter a common Naval Engineering Curriculum. Entrance to this curriculum is semi-annually in March and September. At the end of the second quarter, students may elect to pursue studies in a specialty of either MECHANICAL or ELECTRICAL engineering. Upon completion of the first year of study, qualified students are selected to follow a master's degree curriculum in one of the several specialty areas. After completion of seven quarters, students from the M. S. group are further selected to follow an Engineer degree curriculum in either mechanical or electrical engineering.

The criteria for selection are academic performance, individual preference, and tour availability.

The length of each curriculum is dependent upon the qualifications and prior education of each student. While well-qualified students can complete the respective curricula in a shorter time than indicated, by receiving credit for prior academic programs, *the length of each sample program given below is based on a minimal preparation prior to admission:*

Mechanical Engineering (B.S. Degree)
7 quarters

Mechanical Engineering (M.S. Degree)
9 quarters

Mechanical Engineering (Engineer's Degree) — 12 quarters

Electrical Engineering (B.S. Degree)
7 quarters

Electrical Engineering (M.S. Degree)
9 quarters

Electrical Engineering (Engineer's Degree)
12 quarters

The completion of a satisfactory thesis is required for the M.S. and Engineer degree in each specialty. An acceptable thesis for the Engineer's degree is acceptable for meeting the thesis requirements of the Master's degree. Selected Naval Academy, NROTC, and OCS graduates may enter directly into a graduate program (IGEP) and obtain a Master's degree upon completion of four quarters course work, including an acceptable thesis.

A limited number of officers who demonstrate superior academic performance and are otherwise eligible may apply for doctoral level studies in mechanical or electrical engineering. Successful completion of these studies leads to the award of the degree of Doctor of Philosophy.

Those officers successfully completing these programs will be identified as subspecialists in accordance with the current Bureau of Naval Personnel Instructions.

By the very nature of the mechanical and electrical engineering disciplines, considerable flexibility in the development of individual student programs is possible. *Accordingly, the following programs should be considered as typical ones rather than as rigid and standardized:*

NAVAL ENGINEERING (GENERAL PROGRAM) (GROUP NG)

Common to all Naval Engineering students

First Quarter

MA	1100	Calculus Review	4- 0
MA	2045	Introduction to Linear Algebra	3- 0
EE	2101	Basic Circuit Theory	3- 2
ME	2610	Mechanics of Solids I	5- 2
			15- 4

Second Quarter

MA	2121	Differential Equations	4- 0
EE	2102	Circuit Analysis	4- 2
ME	2101	Engineering Thermodynamics	4- 1
ME	2502	Dynamics	4- 0
			16- 3

MECHANICAL ENGINEERING (B.S.M.E.) (GROUP NH)

Third Quarter

MA	2232	Numerical Methods	3- 1
ME	2201	Introduction to Fluid Mechanics	3- 2
ME	3611	Mechanics of Solids II	4- 0
ME	2410	Mechanical Engineering Lab I	2- 3
			12- 6

Fourth Quarter

MA	3132	Partial Differential Equations and Integral Transforms	4- 0
ME	3150	Heat Transfer	4- 2
ME	3201	Principles of Fluid Dynamics	3- 1
MS	2201	Engineering Materials	3- 2
			14- 5

Fifth Quarter

ME 3301	Nuclear Power Systems	5- 0
ME 3440	Engineering Systems Analysis	4- 0
ME 3521	Mechanical Vibrations	3- 2
ME 3711	Design of Machine Elements	3- 2
		15- 4

Sixth Quarter

ME 3430	Mechanical Engineering Lab II	1- 3
ME 3450	Thermodynamics of Marine Power Systems	3- 2
MS 3202	Properties of Structural Materials	3- 2
EE 2201	Electronics Survey	4- 2
		11- 9

Seventh Quarter

EE 3413	Fundamentals of Automatic Control	3- 3
ME 3202	Gas Dynamics	3- 1
OS 3201	Fundamentals of Operations Analysis	4- 0
MN 3170	Defense Resource Allocation	4- 0
		14- 4

MECHANICAL ENGINEERING (M.S.M.E.) ENGINEERING MECHANICS (GROUP NS)

Quarters 3, 4 and 5 same as for Group NH above

Sixth Quarter

ME 3430	Mechanical Engineering Lab II	1- 3
ME 3450	Thermodynamics of Marine Power Systems	3- 2
ME 3712	Design of Machinery	2- 4
ME 4512	Advanced Dynamics	4- 0
		10- 9

Seventh Quarter

EE 3413	Fundamentals of Automatic Control	3- 3
ME 4522	Advanced Vibrations	4- 0
ME 4613	Finite Element Methods	4- 0
ME 0810	Thesis Research	0- 0
		11- 3

Eighth Quarter

ME 4612	Advanced Mechanics of Solids	4- 0
MS 3202	Properties of Structural Materials	3- 2
ME 0810	Thesis Research	0- 0
		7- 2

Ninth Quarter

OS 3201	Fundamentals of Operations Analysis	4- 0
MN 3170	Defense Resource Allocation	4- 0
ME 0810	Thesis Research	0- 0
		8- 0

MECHANICAL ENGINEERING (M.S.M.E.) THERMO-FLUID SCIENCES (GROUP NF)

Quarters 3, 4 and 5 same as for Group NH above

Sixth Quarter

ME 3430	Mechanical Engineering Lab II	1- 3
ME 3450	Thermodynamics of Marine Power Systems	3- 2
ME 4161	Conduction and Radiation Heat Transfer	4- 0
ME 4211	Hydrodynamics	4- 0
		12- 5

Seventh Quarter

EE 3413	Fundamentals of Automatic Control	3- 3
ME 3202	Gas Dynamics	3- 1
ME 4220	Viscous Flow	4- 0
ME 0810	Thesis Research	0- 0
		10- 4

Eighth Quarter

ME 3801	Fluid Power Control	3- 2
ME 4162	Convection Heat Transfer	4- 0
ME 0810	Thesis Research	0- 0
		7- 2

Ninth Quarter

OS 3201	Fundamentals of Operations Analysis	4- 0
MN 3170	Defense Resource Allocation	4- 0
ME 0810	Thesis Research	0- 0
		8- 0

MECHANICAL ENGINEERING (M.S.M.E.) OCEAN MECHANICAL (GROUP NO)

Quarters 3, 4 and 5 same as for Group NH above

Sixth Quarter

ME 3430	Mechanical Engineering Lab II	1- 3
ME 3450	Thermodynamics of Marine Power Systems	3- 2
ME 4211	Hydrodynamics	4- 0
OC 3221	Descriptive Physical Oceanography	4- 0
		12- 5

Seventh Quarter

ME 4220	Viscous Flow	4- 0
OC 3250	Dynamical Oceanography	4- 0
OC 3801	Ocean Operations I	3- 1
ME 0810	Thesis Research	0- 0
		11- 1

Eighth Quarter

ME 3801	Fluid Power Control	3- 2
OC 4802	Ocean Operations II	3- 1
ME 0810	Thesis Research	0- 0
		6- 3

Ninth Quarter

MN 3170	Defense Resource Allocation	4- 0
OS 3201	Fundamentals of Operations Analysis	4- 0
ME 0810	Thesis Research	0- 0
		8- 0

MECHANICAL ENGINEERING ENGINEER PROGRAMS

To achieve the degree, *Mechanical Engineer*, the student must complete an additional three quarters of study beyond the requirements for the Master of Science degree. Additional courses are taken to give a more comprehensive understanding of the previously selected area of specialization. Thesis research for the Engineer's degree is equivalent to approximately seven courses. In addition, an industrial tour of six-weeks' duration gives opportunity for the student to work directly with engineers on a problem in his area of specialization.

Specialization Courses, Engineering Mechanics

ME	4140	Direct Energy Conversion
ME	4211	Hydrodynamics
ME	4220	Viscous Flow
ME	4620	Theory of Continuous Media
ME	4902	Advanced Study in Mechanical Engineering
MA	4611	Calculus of Variations

Specialization Courses, Thermo-Fluid Sciences

ME	4140	Direct Energy Conversion
ME	4240	Advanced Hydrodynamics
ME	4321	Reactor Engineering Principles and Design
ME	4512	Advanced Dynamics
ME	4620	Theory of Continuous Media
ME	4902	Advanced Study in Mechanical Engineering
MA	3173	Complex Variables and Laplace Transforms

Specialization Courses, Ocean Mechanical Engineering

ME	4140	Direct Energy Conversion
ME	4240	Advanced Hydrodynamics
ME	4612	Advanced Mechanics of Solids
ME	4902	Advanced Study in Mechanical Engineering
OC	4601	Ocean Wave Forecasting
OC	4211	Waves and Tides
OC	4321	Introductory Geophysical Fluid Dynamics
OC	4422	Marine Biodeterioration

Nuclear Engineering — while no formal specialty program in the Nuclear Engineering area is offered currently, several courses are available for interested students:

ME	3315	Nuclear Measurements Lab
ME	3341	Radiation Shielding
ME	4311	Nuclear Reactor Analysis I
ME	4312	Nuclear Reactor Analysis II
ME	4321	Reactor Engineering Principles and Design

ELECTRICAL ENGINEERING (B.S.E.E.) (GROUP NE)

Quarters 1 and 2 same as Group NG

Third Quarter

EE	2103	Linear Systems Analysis	4- 2
MA	2172	Complex Variable	4- 0
CS	2100	Introduction to Computers and FORTRAN Programming	4- 0
PS	3411	Applied Probability Theory I	4- 0
			16- 2

Fourth Quarter

EE	2211	Electronic Engineering Fundamentals I	4- 2
EE	2810	Digital Machines	3- 3
EE	2411	Control Systems	3- 3
EE	2621	Introduction to Fields and Waves	4- 0
			14- 8

Fifth Quarter

EE	2311	Principles of Energy Conversion	3- 2
EE	2212	Electronic Engineering Fundamentals II	4- 3
EE	2622	Electromagnetic Engineering	3- 1
EE	2114	Communication Theory I	4- 0
			14- 6

Sixth Quarter

EE	2216	Pulse and Digital Circuits	4- 3
EE	3631	Antennas and Propogation	3- 2
EE	3263	Integrated Circuits	3- 3
EE	4121	Advanced Network Theory I	3- 2
			13-10

Seventh Quarter

PH	2810	Survey of Nuclear Physics	4- 0
EE	3312	Electromagnetic Machines	3- 4
OS	3202	Methods of Operations Analysis/ Systems Analysis	4- 0
MN	3170	Defense Resource Allocation	4- 0
			15- 4

ELECTRICAL ENGINEERING (M.S.E.E.) SHIPBOARD CONTROLS

Quarters 1 through 6 same as for Group NE above

Seventh Quarter

EE	3312	Electromagnetic Machines	3- 4
EE	4412	Nonlinear Systems	3- 3
EE	4417	Optimal Control	4- 0
EE	0810	Thesis Research	0- 0
			10- 7

Eighth Quarter

EE	3313	Marine Electrical Analysis and Design	2- 4
EE	4414	Stochastic Control Theory	2- 2
OS	3202	Methods of Operations Analysis/ Systems Analysis	4- 0
EE	0810	Thesis Research	0- 0
			8- 6

Ninth Quarter

EE	3822	Engineering Application of Computers	3- 3
MN	3170	Defense Resource Allocation	4- 0
EE	0810	Thesis Research	0- 0
			7- 3

ELECTRICAL ENGINEERING (M.S.E.E.) INFORMATION PROCESSING

Quarters 1 through 6 same as for Group NE above

Seventh Quarter

EE	4571	Statistical Communication Theory	3- 2
EE	4412	Nonlinear Systems	3- 3
EE	3822	Engineering Applications of Computers	3- 3
EE	0810	Thesis Research	0- 0
			9- 8

Eighth Quarter

EE	3812	Switching Theory and Logic Design	3- 2
EE	4414	Stochastic Control Theory	2- 2
OS	3202	Methods of Operations Analysis/ Systems Analysis	4- 0
EE	0810	Thesis Research	0- 0
			9- 4

Ninth Quarter

EE	4823	Advanced Digital Computer Systems	3- 1
MN	3170	Defense Resource Allocation	4- 0
EE	0810	Thesis Research	0- 0
			7- 1

ELECTRICAL ENGINEERING (M.S.E.E.)
ELECTRONICS SYSTEMS

Quarters 1 through 6 same as for Group NE above

Seventh Quarter

EE	3631	Antennas and Propagation	3- 2
EE	3822	Engineering Applications of Computers	3- 3
EE	4571	Statistical Communication Theory	3- 2
EE	0810	Thesis Rsearch	0- 0
			9- 7

Eighth Quarter

EE	4461	Advanced Systems Engineering	3- 1
EE	4433	Advanced Radar Systems	3- 2
OS	3202	Methods of Operations Analysis/ Systems Analysis	4- 0
EE	0810	Thesis Research	0- 0
			10- 3

Ninth Quarter

EE	3471	Guidance and Navigation	3- 2
MN	3170	Defense Resource Allocation	4- 0
EE	0810	Thesis Research	0- 0
			7- 2

ELECTRICAL ENGINEERING
ENGINEER PROGRAMS

Programs leading to the degree of *Electrical Engineer* are individually arranged in consultation with an advisor appointed by the Department of Electrical Engineering. Opportunity is provided to specialize in control systems, communications, and information theory, or computer technlogy. In addition to completing the courses listed for the Master of Science degree, the student will take the courses indicated for his area of specialization, plus a minimum of nine electives. Thesis research for the Engineer degree is equivalent to approximately seven courses. An industrial tour of six-weeks' duration gives opportunity for the student to work directly with engineers on a problem in his area of specialization.

Spanagel Hall

OPERATIONS RESEARCH/SYSTEMS ANALYSIS PROGRAM

CURRICULUM NUMBER 360

JOHN DONALD HARTLEY, Commander, U. S. Navy; Curricular Officer; B.S. Naval Academy, 1952; Naval Postgraduate School, 1964.

WILLIAM PEYTON CUNNINGHAM, Academic Associate for Operations Analysis; B.S., Yale University, 1928; Ph.D., 1932.

JEROME EDWARD MCCUE, Lieutenant Commander, U. S. Navy; Assistant Curricular Officer; B.S., St. Joseph's College, 1958; Naval Postgraduate School, 1971.

OPERATIONS RESEARCH/SYSTEMS ANALYSIS CURRICULUM CURRICULUM NUMBER 360 (GROUP RO)

OBJECTIVE — To provide selected officers with a sound education in quantitative methods and to develop their analytical ability in order that they may (1) formulate new concepts and apply the results of operations research/systems analysis with greater effectiveness, and (2) define and solve military problems more effectively.

QUALIFICATIONS FOR ADMISSION — A baccalaureate degree with above-average grades in mathematics is required. Completion of mathematics through differential and integral calculus is considered minimal preparation. A one year course in college physics is highly desired (Supply Officers excluded). Students lacking these quantitative prerequisites will be accepted, in certain special cases, where their undergraduate records indicate that they are exceptional students and there are other possible indicators of success such as Graduate Record Examination scores, correspondence or extension courses in quantitative areas, and outstanding motivation for the program.

DESCRIPTION — The Operations Research/Systems Analysis program is interdisciplinary in nature, consisting of course work in operations analysis, probability and statistics, mathematics, physics, economics, and computer science. Classes convene semiannually, in March and September. All students take a common core curriculum during the first year (four quarters) although there are slight variations designed to meet particular career needs of Navy Line, Supply Corps, Marine Corps, Army and Air Force officers. Those officers selected for the Master's program continue for a second year of study (for a total of eight quarters, overall) and are afforded the opportunity to qualify for the degree of Master of Science in Operations Research. Additionally, students in the master's program must complete an elective sequence approved by the Department of Operations Research and Administrative Sciences and submit an acceptable thesis on a subject previously approved by the Department.

An integral part of the master's program is a six-week intersessional experience tour taken during the second half of the fifth quarter in which the student officers are assigned as working members of appropriate military or industrial groups engaged in operations research/systems analysis of military problems. This field trip is designed to permit the student, on an individual basis, to participate in some phase of active operations research in the "real world," and, secondarily, to assist him in finding a problem of interest for subsequent thesis study.

Selection for the master's program is based on the student's academic performance and potential. Those officers not selected for the master's program are graduated at the end of five quarters, and upon successful completion, are awarded the degree of Bachelor of Science in Operations Research.

At present, all Naval officers successfully completing either the eight-quarter master's program or the five-quarter bachelor's program are considered qualified to fill Operations Analysis Sub-specialist P-Coded billets, 8510P or 8510S, respectively.

An important adjunct to the formal classroom work is a seminar series in which guest lecturers present first-hand information as to practical principles and techniques in the field of Operations Research/Systems Analysis.

Officers who possess outstanding quantitative backgrounds by virtue of having completed other graduate education, or undergraduate work with a major in operations research or the equivalent, may be enrolled in a special master's degree program of about one year's duration. The specific curriculum in each case must be approved by the Department of Operations Research and Administrative Sciences and will be designed to meet the needs of the service, while complementing the officer's past educational background.

A limited number of officers each year who demonstrate superior academic performance are encouraged to apply for doctoral study in operations research.

Refresher (six weeks)

MA	0111	Refresher Mathematics	5- 5
MA	0125	Logic and Set Theory	5- 0
PH	0110	Refresher Physics	5- 3
CS	0110	FORTRAN Programming	3- 0
			18- 8

First Quarter

MA	2109	Multivariable Calculus	5- 0
MA	2042	Linear Algebra	4- 0
OA	2301	Probability	4- 0
OA	2600	History and Nature of Operations Analysis	2- 0
OA	2601	Introduction to Decision Analysis	2- 0
OA	0001	Seminar for OR/SA students	0- 2
			17- 2

Second Quarter

MA	2110	Selected Topics from Advanced Calculus	4- 0
OA	3302	Probability and Statistics	4- 1
PH	2121	Analysis of Physical Models I	4- 0
OA	3657	Human Factors in Systems Design I	4- 0
OA	0001	Seminar for OR/SA students	0- 2
			16- 3

Third Quarter

OA 3609	Introduction to Mathematical Economics	4- 0
OA 3604	Linear Programming	4- 0
OA 3303	Statistics	4- 1
OA 3653	System Simulation	4- 0
OA 0001	Seminar for OR/SA students	0- 2
		16- 3

Fourth Quarter

OA 3610	Utility Theory and Resource Allocation Models	4- 0
OA 3660	Analysis of Operational Data	3- 1
OA 3704	Stochastic Models I	4- 0
PH 2122	Analysis of Physical Models II	4- 2
	or	
OA 3620	Inventory I (Supply)	4- 0
OA 0001	Seminar for OR/SA students	0- 2
		15- 5

Fifth Quarter (Master's Program)

During the first six weeks of the Quarter, students will take two courses at an eccelerated pace:

OA 3611	Systems Analysis I	4- 0
OA 3654	War Gaming	3- 2
OA 0001	Seminar for OR/SA students	0- 2
		7- 4

The student experience tour is taken during the last six weeks of the Quarter.

Fifth Quarter (Bachelor's Program)

OA 3605	Methods of OR/SA	4- 0
OA 3611	Systems Analysis I	4- 0
OA 3900	Workshop in OR/SA	4- 0
OA 3910	Selected Topics in OR/SA	4- 0
OA 0001	Seminar for OR/SA students	0- 2
		16- 2

Sixth Quarter (Master's Program)

OA 4631	Non-Linear and Dynamic Programming	4- 0
OA 4705	Stochastic Models II	4- 0
*OA 4651	Search Theory and Detection	4- 0
*OA 4654	Mathematical Models of Combat	4- 0
*OA 4621	Inventory II (Supply)	4- 0
OA 0001	Seminar for OR/SA students	0- 2
	Elective	3- 0 to 4- 0
OA 0810	Thesis Research for OR/SA Students	0- 0
		15- 2 to 16- 2

Seventh Quarter (Master's Program)

OA 4662	Reliability and Weapons Systems Effectiveness Measurement	4- 0
*OA 4614	Methods and Practice of Systems Analysis	4- 0
*OA 4633	Networks Flows and Graphs	4- 0
*PH 3421	Underwater Acoustics	4- 2
*OA 3671	Cybernetics and Analysis of Information Systems	4- 0
OA 0001	Seminar for OR/SA students	0- 2
	Elective	3- 0 to 4- 0
OA 0810	Thesis Research for OR/SA Students	0- 0
		11- 2 to 12- 4

*Select one only

Eighth Quarter (Master's Program)

OA 3612	Systems Analysis II	4- 0
OA 4622	Seminar in Supply Systems (Supply)	4- 0
	Elective	3- 0 to 4- 0
	Elective	3- 0 to 4- 0
OA 0001	Eeminar for OR/SA students	0- 2
OA 0810	Thesis Research for OR/SA Students	0- 0
		14- 2 to 16- 2

ELECTIVES

All students in the Master's program must complete an elective sequence of at least three courses approved by the Department of Operations Research and Administrative Sciences. Electives may be chosen from the following list of courses (although it should be noted that only certain courses will be offered in any particular quarter):

OA 3620	Inventory I
OA 4621	Inventory II
OA 3656	Operations Research Problems in Special Warfare
OA 3658	Human Factors in Systems Design II
OA 3660	Analysis of Operational Data
OA 3664	Theory of Pattern Recognition
OA 4613	Theory of Systems Analysis
OA 4615	Econometrics
OA 4632	Mathematical Programming
OA 4633	Networks Flows and Graphs
OA 4634	Games of Strategy
OA 4635	Non-Linear Programming
OA 4636	Dynamic Programming
OA 4642	Advanced Topics in War Gaming and Simulation
OA 4652	Operations Research Problems in Naval Warfare
OA 4662	Reliability and Weapons System Effectiveness Measurement
OA 4680	Human Performance Evaluation
OA 4706	Stochastic Models III
OA 4910	Selected Topics in OR/SA
OA 4306	Applied Statistics
OA 4321	Design of Experiments
OA 4323	Decision Theory
OA 4431	Advanced Probability
OA 4432	Stochastic Processes I
OA 4433	Stochastic Processes II
OA 4440	Time Series Analysis
OA 4510	Selected Topics in Probability and Statistics
MN 3130	Macroeconomic Theory
MN 4931	Macroeconomic Theory
MN 4941	Microeconomic Theory
CS 3111	Fundamental Concepts in Structural Programming Languages
CS 3112	Operating Systems
PH 3421	Underwater Acoustics
PH 3921	Conceptual Models of Modern Physics

ORDNANCE ENGINEERING PROGRAMS
CURRICULAR NUMBERS 521, 530 and 535

George Clarence Sup, Commander, U. S. Navy; Curricular Officer; B.S. in Physics, Naval Postgraduate School, 1960.

John Norvell Dyer, Academic Associate; B.A., University of California at Berkeley, 1956; Ph.D., 1960.

Herbert Marshall Effron, Lieutenant Commander, U. S. Navy; Assistant Curricular Officer; B.A. in Chemistry, San Jose State College, 1958; M.S. in Physics, Naval Postgraduate School, 1967.

NUCLEAR SCIENCE (EFFECTS)
CURRICULUM NUMBER 521

OBJECTIVE — Through graduate education, provide officers with an increased level of scientific and technical knowledge underlying the effects of nuclear weapons in order to blend their professional expertise with sufficient technical competence for duty assignments in this subspecialty area of warfare.

QUALIFICATIONS FOR ADMISSION — Above-average grades in mathematics, physical sciences and engineering courses; must have completed calculus and one year of engineering physics. Courses in chemistry, mechanics, thermodynamics and electrical engineering are very desirable.

DESCRIPTION — This curriculum is sponsored by the Office of Naval Research for officers of the Navy and Marine Corps, and by the respective services for officers of the Army, Air Force, and Coast Guard. Classes convene in March and September; curriculum duration is twenty-seven months. Successful completion of the curriculum leads to award of the degree, Master of Science in Physics. Subject to approval of the parent service, the academically-superior student may continue studies leading to award of the degree, Doctor of Philosophy (majoring in physics).

The Nuclear Science (Effects) Curriculum is designed to provide the officer student with a well-founded comprehension of scientific and technical principles underlying the blast, thermal, and radiation effects associated with nuclear weapons. Principal studies are undertaken in classical and modern physics as the foundation science to understand these effects. Concurrent studies of electrical and electronic devices and circuits, as well as studies in other fields such as operations analysis, complete this comprehensive program. Specialized areas of study include nuclear processes, plasmas, radiation and thermal effects in matter (including electronic devices and living organisms), generation and propagation of shock waves, and properties of the upper atmosphere. Thesis research is normally conducted in one of these areas of specialized study. Completion of the curriculum permits the officer to more knowledgeably address current and future military problems associated with weapons effects and expands his base of professional knowledge and technical competence.

For officers who can report early, the curriculum is preceded by a non-credit, six-week refresher period which provides courses in basic mathematics (through calculus), physics, electrical engineering, and chemistry. (A non-credit course in FORTRAN programming is also offered for those students who can academically accommodate this additional course.) The refresher period and the first five quarters of the nine-quarter curriculum are designed to provide a smooth transition from previous studies and provide the sound undergraduate background necessary for the subsequent advanced courses and thesis research. Portions of this undergraduate preparation may be validated by the better academically-prepared officer to permit study to a greater depth or breadth in graduate electives; or subject to course scheduling limitations, shorten his time on board. Officers less academically prepared may first be enrolled in the Engineering Science Curriculum for one or more quarters to improve their probability for success in Nuclear Science (Effects).

Early in the second year of instruction officers are evaluated for academic progress, accomplishments, and potential to complete the remaining portion of the curriculum. Those officers who have demonstrated a capability to satisfy academic requirements for the Master of Science degree will continue in the regular curriculum and select an area of specialized study for thesis research. The officers who are unable to continue in graduate-level work will normally be scheduled to complete their studies in seven, vice nine, quarters and will receive the degree Bachelor of Science in Physics provided academic requirements are satisfied.

Naval officers of the unrestricted line graduating from this program are recommended for the subspecialty qualification code 8443P. Billet requirements for naval officers who have been assigned this code are contained in the *Annual Naval Officer Billet Summary.*

REPRESENTATIVE CURRICULUM
(GROUP FA)

First Quarter			
MA	1100	Calculus Review	4- 0
MA	2045	Introduction to Linear Algebra	3- 0
PH	1051	Review of Vector Mechanics and Optics	4- 2
EE	2101	Basic Circuit Theory	3- 2
			14- 4
Second Quarter			
MA	2121	Differential Equations	4- 0
CS	2100	Introduction to Computers and FORTRAN Programming	4- 0
PH	2151	Mechanics I	4- 0
EE	2201	Electronics Survey	4- 2
			16- 2
Third Quarter			
MA	2161	Introduction to Mathematical Physics	4- 0
MA	2172	Complex Variables	4- 0
PH	2152	Mechanics II	4- 0
PS	2315	Data Reduction and Error Analysis	4- 0
			16- 0

Fourth Quarter

PH	2351	Electromagnetism I	4- 0
PH	2551	Thermodynamics	3- 0
PH	2251	Waves and Particles	4- 2
OA	3659	Human Factors Engineering	3- 0
			14- 2

Fifth Quarter

PH	2352	Electromagnetism II	3- 0
PH	3951	Introduction to Quantum Mechanics	4- 0
PH	3461	Explosive Shock Waves	4- 0
PH	3651	Atomic Physics	4- 2
PH	0999	Physics Colloquium	0- 1
			15- 3

Sixth Quarter

PH	4353	Electromagnetism III	3- 0
PH	3280	Electro-Optics	4- 2
PH	3561	Introductory Statistical Physics	4- 0
PH	3652	Elements of Molecular, Solid State, and Nuclear Physics	4- 2
PH	0999	Physics Colloquium	0- 1
			15- 5

Seventh Quarter

PH	4661	Plasma Physics I	4- 0
PH	4851	Nuclear Physics	4- 2
PH	0810	Thesis Research	0- 0
PH	0999	Physics Colloquium	0- 1
PH	xxxx	Graduate Elective	4- 0
			12- 3

Eighth Quarter

BI	3850	Biological Effects of Radiation	5- 0
PH	0810	Thesis Research	0- 0
PH	0999	Physics Colloquium	0- 1
PH	xxxx	Graduate Elective	4- 0
			9- 1

Ninth Quarter

PH	4630	Space Physics I	4- 0
PH	4750	Radiation Effects in Solids	5- 0
PH	0810	Thesis Research	0- 0
PH	0999	Physics Colloquium	0- 1
			9- 1

ORDNANCE SYSTEMS ENGINEERING CURRICULUM NUMBER 530

OBJECTIVE — Through graduate education, provide officers with an increased level of scientific and technical knowledge underlying the broad field of Ordnance Engineering in order to blend their professional expertise with sufficient technical competence for duty assignments in this subspecialty area of naval warfare.

QUALIFICATIONS FOR ADMISSION — Above-average grades in mathematics, physical sciences and engineering courses; must have completed calculus and one year of engineering physics. Courses in chemistry, mechanics, thermodynamics and electrical engineering are very desirable. Allied officers may enroll in this curriculum subject to the exclusion of classified courses as determined by the Chief of Naval Operations.

DESCRIPTION — This curriculum is sponsored by the Naval Ordnance Systems Command for officers of the Navy and Marine Corps, and by the respective services for officers of the Army, Air Force, and Coast Guard. Classes convene in March and September; curriculum duration is twenty-seven months. Subject to approval of the parent service, the academically superior student may continue studies leading to award of the professional degree, Electrical Engineer, or the Doctor of Philosophy (majoring in physics or electrical engineering).

The Ordnance Systems Engineering Curriculum is designed to provide the officer students with a well-founded comprehension of the scientific and technical principles underlying the broad field of ordnance engineering. Subject to service needs, the student may select a program of study majoring in physics, electrical engineering, or chemistry. Studies in the principal field are augmented by cross-field studies (for example, electrical engineering courses for physics majors) as well as studies in associated areas such as operations analysis. Specialized areas of study include options and thesis research which are described below in the program listings. Successful completion of the curriculum leads to award of the degree, Master of Science in the principal field, permits the officer to more knowledgeably address current and future military problems associated with ordnance systems, and expands his base of professional knowledge and technical competence.

For officers who can report early, the curriculum is preceded by a non-credit, six-week refresher period which provides courses in basic mathematics (through calculus), physics, electrical engineering, and chemistry. (A non-credit course in FORTRAN programming is also offered for those students who can academically accommodate this additional course.) The refresher period and the first five quarters of the nine-quarter curriculum are designed to provide a smooth transition from previous studies and to provide the sound undergraduate background necessary for the subsequent advanced courses and thesis research. Portions of this undergraduate preparation may be validated by the better academically-prepared officer to permit study to a greater depth or breadth in graduate electives; or subject to course scheduling limitations, shorten his time on board. Officers less academically prepared may first be enrolled in the Engineering Science Curriculum for one or more quarters to improve their probability for success in Ordnance Engineering.

Early in the second year of instruction officers are evaluated for academic progress, accomplishments, and potential to complete the remaining portion of the curriculum. Those officers who have demonstrated a capability to satisfy academic requirements for the Master of Science degree will continue in the regular curriculum and select an area of specialized study for thesis research. The officers who are unable to continue in graduate-level work will normally be scheduled to complete their studies in seven, vice nine, quarters and will receive the degree Bachelor of Science in their major field provided academic requirements are satisfied.

The following representative programs are designed to be academically sound, consistent with the service needs for technical knowledge and basic

qualification requirements specified by the Naval Ordnance Systems Command, and permit selection of electives of interest to the student. Upon successful completion of the curriculum, unrestricted line officers will be recommended for subspecialty qualification codes as follows:

Physics majors	8310P
Chemistry majors	8320P
Electrical Engineering majors	8330P

P-coded billet requirements are listed in the publication, *Annual Naval Officer Billet Summary.*

ORDNANCE SYSTEMS ENGINEERING (CHEMISTRY)

OBJECTIVE — To enhance over-all professional capability by providing broad coverage of general subject matter, and to study in depth in one particular aspect of applied or theoretical chemistry of interest to the Navy and to the individual officer. The applied chemistry portions cover practical aspects that range from application through development and manufacture of current and future chemical systems such as explosives, plastics, and fuels. The theoretical portions provide the concepts of molecular engineering and an understanding of basic chemical processes such as those of explosion, corrosion, electrochemical fuel cells, and biological effects. Classroom instruction is complemented by independent thesis research; digital computer computations may be an integral part of each.

REPRESENTATIVE CURRICULUM (CHEMISTRY)

First Quarter

MA 1100	Calculus Review	4- 0
MA 2045	Introduction to Linear Algebra	3- 0
PH 1051	Review of Vector Mechanics and Optics	4- 2
EE 2101	Basic Circuit Theory	3- 2
		14- 4

Second Quarter

MA 2121	Differential Equations	4- 0
CH 2001	General Principles of Chemistry	3- 2
CH 2401	Chemical Thermodynamics	3- 0
EE 2201	Electronics Survey	4- 2
		14- 4

Third Quarter

MA 2161	Introduction to Mathematical Physics	4- 0
CH 2101	Inorganic Analysis	3- 3
CH 2402	Physical Chemistry I	3- 3
PH 2151	Mechanics I	4- 0
		14- 6

Fourth Quarter

CH 2301	Organic Chemistry I	4- 3
CH 2102	Inorganic Chemistry	3- 3
CH 2403	Physical Chemistry Topics	4- 3
		11- 9

Fifth Quarter

CH 2302	Organic Chemistry II	3- 3
CH 2201	Chemical Instruments	3- 3
PS 2315	Data Reduction and Error Analysis	4- 0
PH 2251	Waves and Particles	4- 0
		14- 6

Sixth Quarter

CH 3415	Statistical Mechanics	4- 0
CH 3101	Advanced Inorganic Chemistry	3- 3
CH 3405	Molecular Dynamics	5- 0
		12- 3

Seventh Quarter

CH 3301	Physical Organic I	3- 0
CH 0800	Chemistry Seminar	0- 1
CH 0810	Thesis Research	0- 0
	Graduate Option Elective	4- 0
		7- 1

Eighth Quarter

CH 0800	Chemistry Seminar	0- 1
CH 0180	Thesis Research	0- 0
	Graduate Option Elective	4- 0
	Graduate Option Elective	4- 0
		8- 1

Ninth Quarter

CH 0800	Chemistry Seminar	0- 1
CH 0810	Thesis Research	0- 0
	Graduate Option Elective	4- 0
	Graduate Option Elective	4- 0
		8- 1

ORDNANCE SYSTEMS ENGINEERING (ELECTRICAL ENGINEERING)

OBJECTIVE — To educate officers in the fundamentals of electrical engineering and its application to modern ordnance. Basic principles of electronics, electromagnetics theory, and control theory provide a starting point for advanced study and thesis research in modern feedback control theory, information transfer theory, and electronic systems including radar, sonar, missile guidance, and computers. Graduates of this program will have the technical competence required in the research design, development, production, maintenance, and operation of advanced electronic and electromechanical systems.

DESCRIPTION — A program of study may be undertaken in the option areas of advanced electrical engineering systems or computer engineering. Studies in advanced electrical engineering systems include radar, missile guidance, and electronic warfare. Studies in computer engineering provide knowledge applicable to the engineering applications of digital, analog, and hybrid computers to ordnance systems.

REPRESENTATIVE CURRICULUM (ELECTRICAL ENGINEERING)

First Quarter

MA 1100	Calculus Review	4- 0
MA 2045	Introduction to Linear Algebra	3- 0
PH 1041	Review of Mechanics and Electricity and Magnetism	5- 1
EE 2101	Basic Circuit Theory	3- 2
		15- 3

Second Quarter

MA	2121	Differential Equations	4- 0
CS	2100	Introduction to Computers and FORTRAN Programming	4- 0
EE	2211	Electronic Engineering Fundamentals I	4- 2
EE	2102	Circuit Analysis	4- 2
			16- 4

Third Quarter

MA	2172	Complex Variables	4- 0
EE	2810	Digital Machines	3- 3
EE	2212	Electronic Engineering Fundamentals II	4- 3
EE	2103	Linear Systems Analysis	4- 2
			15- 8

Fourth Quarter

PH	2241	Waves and Particles	4- 0
EE	2621	Introduction to Fields and Waves	4- 0
EE	2216	Pulse and Digital Circuits	4- 3
EE	2114	Communication Theory I	4- 0
			16- 3

Fifth Quarter

PH	2641	Atomic Physics	4- 2
EE	2622	Electromagnetic Engineering	3- 1
EE	2217	Communication Circuits	4- 3
EE	2411	Control Systems	3- 3
EE	0951	Thesis Seminar	0- 1
			14-10

GENERAL EE

Sixth Quarter

EE	3215	Microwave Devices	4- 2
EE	4121	Advanced Network Theory I	3- 2
PS	3411	Applied Probability Theory I	4- 1
EE	3822	Engineering Applications of Computers	3- 3
EE	0951	Thesis Seminar	0- 1
			14- 9

Seventh Quarter

EE	4433	Advanced Radar Systems	3- 2
EE	4412	Nonlinear Systems	3- 3
EE	4571	Statistical Communication Theory	3- 2
EE	0951	Thesis Seminar	0- 1
EE	xxxx	Graduate Elective	4- 0
			13- 8

Eighth Quarter

EE	4473	Missile Guidance Systems	3- 1
EE	0810	Thesis Research	0- 0
EE	0951	Thesis Seminar	0- 1
EE	xxxx	Graduate Elective	4- 0
			7- 2

Ninth Quarter

EE	4481	Electronic Warfare Techniques and Systems	3- 3
EE	0810	Thesis Research	0- 0
EE	0951	Thesis Seminar	0- 1
EE	xxxx	Graduate Elective	4- 0
			7- 4

COMPUTER SYSTEMS

Sixth Quarter

EE	3812	Switching Theory and Logic Design	3- 2
EE	3263	Integrated Circuits	3- 3
		or	
EE	3215	Microwave Devices	4- 2
CS	3111	Fundamental Concepts in Structural Programming Languages	4- 0
EE	3822	Engineering Applications of Computers	3- 3
EE	0951	Seminar	0- 1
			13- 9 or 14- 8

Seventh Quarter

CS	3204	Data Communications	4- 0
EE	0810	Thesis Research	0- 0
EE	0951	Seminar	0- 1
EE	xxxx	Graduate Elective	4- 0
EE	xxxx	Graduate Elective	4- 0
			12- 1

Eighth Quarter

EE	4823	Advanced Digital Computer Systems	3- 1
EE	4121	Advanced Network Theory I	3- 2
EE	0810	Thesis Research	0- 0
EE	0951	Seminar	0- 1
EE	xxxx	Graduate Elective	4- 0
			10- 4

Ninth Quarter

CS	4202	Interactive Computation Systems	3- 2
EE	0810	Thesis Research	0- 0
EE	0951	Seminar	0- 1
EE	xxxx	Graduate Elective	4- 0
			7- 3

GRADUATE OPTIONS

Each student in an advanced program will pursue one or more graduate options, each consisting of at least two graduate courses in a specialty area in electrical engineering and related disciplines that are consistent with the student's interests and the objectives of the curriculum. Typical MS and EE programs include three- and twelve-option elective courses respectively. The specialty areas are:

Control Theory. The control theory specialty is designed to provide the student with an understanding of modern methods used in weapon control systems. The concepts and techniques studies are applied to guided missile technology, pursuit-evasion strategies, optimal control policies, and estimation and identification as employed in automatic target tracking and navigational systems.

Electronic Systems. The electronic systems specialty affords students the opportunity for advanced study in the physical principles and processes underlying the operation of modern electronic devices, signal and data processing techniques, electronic circuit design, and systems engineering. These studies are then applied to the understanding of modern electronic systems such as radar, sonar, and electronic countermeasure equipments.

Communication and Information Theory. This specialty includes advanced studies in information transfer, signal and data processing, antennas and propagation, and circuit design. These studies are then applied to the understanding of how information is handled in modern systems such as radar, sonar, digital computers, and electronic countermeasure equipments.

ORDNANCE SYSTEMS ENGINEERING (PHYSICS)

OBJECTIVE — To develop the officer's ability to deal effectively with a broad spectrum of applied technical problems through a study of the fundamental physical processes common to these applications. This is accomplished by a broad coverage of the basic physical principles, combined with advanced courses and independent research in one area of specialization. The basic physics courses cover three broad areas, (a) mechanics and thermo-dynamics including the particle, continuum and statistical aspects; (b) classical electricity and magnetism through electromagnetic radiation theory; and (c) modern physics including atomic and nuclear, quantum mechanics, and space physics.

DESCRIPTION — A program of study in physics may be undertaken in the option areas of electro-optics or missile dynamics. Studies in electro-optics provide knowledge applicable to systems employing the infra-red, visible, and ultraviolet portions of the electromagnetic spectrum. Studies in missile dynamics address the upper atmosphere and the interactions of the missile and its environment.

ORDNANCE SYSTEMS ENGINEERING AIR/SPACE PHYSICS

First Quarter

MA	1100	Calculus Review	4- 0
MA	2045	Introduction to Linear Algebra	3- 0
PH	1051	Review of Vector Mechanics and Optics	4- 2
EE	2101	Basic Circuit Theory	3- 2
			14- 4

Second Quarter

MA	2121	Differential Equations	4- 0
CS	2100	Introduction to Computers and FORTRAN Programming	4- 0
PH	2151	Mechanics I	4- 0
EE	2201	Electronics Survey	4- 2
			16- 2

Third Quarter

MA	2161	Introduction to Mathematical Physics	4- 0
MA	2172	Complex Variables	4- 0
PH	2152	Mechanics II	4- 0
PS	2315	Data Reduction and Error Analysis	4- 0
			16- 0

Fourth Quarter

PH	2351	Electromagnetism I	4- 0
PH	2551	Thermodynamics	3- 0
PH	2251	Waves and Particles	4- 2
PH	xxxx	Elective	4- 0
			15- 2

Fifth Quarter

PH	2352	Electromagnetism II	4- 0
PH	3951	Introduction to Quantum Mechanics	4- 0
PH	3651	Atomic Physics	4- 2
PH	0999	Physics Colloquium	0- 1
PH	xxxx	Elective	4- 0
			16- 3

Sixth Quarter

PH	4353	Electromagnetism III	3- 0
PH	3280	Electro-Optics	4- 2
PH	3561	Introductory Statistical Physics	4- 0
PH	3652	Elements of Molecular, Solid State, and Nuclear Physics	4- 2
PH	0999	Physics Colloquium	0- 1
			15- 5

ELECTRO-OPTICS

Seventh Quarter

PH	4661	Plasma Physics I	4- 0
PH	4281	Electro-Optic Devices	4- 0
PH	3741	Electronic Properties of Metals and Semi-Conductors	4- 2
PH	0810	Thesis Research	0- 0
PH	0999	Physics Colloquium	0- 1
			12- 3

Eighth Quarter

EE	4421	Electro-Optic Systems Engineering	3- 1
PH	0810	Thesis Research	0- 0
PH	0999	Physics Colloquium	0- 1
PH	xxxx	Graduate Elective	4- 0
			7- 2

Ninth Quarter

EE	4422	Topics in Electro-Optic Systems	3- 1
PH	4630	Space Physics I — Physics of the Upper Atmosphere	4- 0
PH	0810	Thesis Research	0- 0
PH	0999	Physics Colloquium	0- 1
			7- 2

MISSILE DYNAMICS

Seventh Quarter

PH	4661	Plasma Physics I	4- 0
PH	3154	Physics of Space Vehicle Dynamics	3- 0
PH	0810	Thesis Research	0- 0
PH	0999	Physics Colloquium	0- 1
PH	xxxx	Graduate Elective	4- 0
			11- 1

Eighth Quarter

PH	4662	Plasma Physics II	3- 0
PH	4151	Physics of Atmospheric Reentry I	4- 0
PH	0810	Thesis Research	0- 0
PH	0999	Physics Colloquium	0- 1
			7- 1

Ninth Quarter

PH	4630	Space Physics I — Physics of the Upper Atmosphere	4- 0
PH	4152	Physics of Atmospheric Reentry II	4- 0
PH	0810	Thesis Research	0- 0
PH	0999	Physics Colloquium	0- 1
			8- 1

GRADUATE OPTIONS

Each student in an advanced program will pursue one or more graduate options, each consisting of at least two graduate courses in a specialty area in physics, and related disciplines that

are consistent with the student's interests and the objectives of the curriculum. The specialty areas are:

Space Physics. This specialization concentrates on those fundamental physical processes in the earth's upper atmosphere and interplanetary space whose understanding is essential to the solution of many applied problems, such as re-entry physics, communication blackouts due to the naturally or artificially disturbed ionosphere, and energy propagation and dissipation at high altitudes.

Plasma Physics. This specialization concentrates on the collective phenomena of ionized media, in which the continuum properties of the assembly of particles are dominant; such phenomena include interaction of plasma with a magnetic field and the occurrence, propagation and dispersion of waves in inhomogeneous plasma. These topics are basic to an understanding of the formation of the ionosphere, ionospheric communication, whistler propagation, re-entry communication, plasma propulsion, MHD power generation and fusion power.

Nuclear Physics. This specialization provides the students with a deeper understanding of basic nuclear processes and phenomena. It acquaints him with the equipment used in nuclear research, especially as needed by an officer to understand the applications of nuclear physics to various branches of current technology.

Radiation Effects (Solids). This specialization concentrates on the effects of radiation on the physical properties of solids and on the operations of solid-state devices. Applications are to micro-electronic devices and to other devices in current use.

Solid State. In solid state physics a wealth of topics is studied such as, lasers; quantum electronics; the structure of crystals, together with their thermal, optical, and acoustic properties; superconductivity; magnetic phenomena; the physics of semiconductors along with their application in various devices; and the electronic properties of metals and insulators. Active research programs are being carried out in several of these areas.

ENGINEERING ACOUSTICS CURRICULUM NUMBER 535

OBJECTIVE — Through graduate education, provide the officer with an increased level of knowledge in the scientific and technical fields underlying acoustic systems used in antisubmarine warfare.

QUALIFICATIONS FOR ADMISSION – Above-average grades in mathematics, physical sciences, and engineering courses; must have completed calculus and one year of engineering physics. Courses in mechanics, optics, oceanography and electrical engineering are very desirable. Allied officers may enroll in this curriculum subject to the exclusion of classified courses as determined by the Chief of Naval Operations.

DESCRIPTION — Classes convene annually in September; curriculum duration is twenty-seven months. Subject to approval of the parent service, the academically-superior student may continue studies leading to award of the professional degree, Electrical Engineer, or the Doctor of Philosophy (majoring in physics or electrical engineering).

The curriculum is interdisciplinary in nature. Courses in oceanography and operations analysis provide knowledge of the ocean environment for acoustic systems and decision theory for realistic problems. The curriculum provides coverage in such areas as propagation of sound in the sea, transducer theory, signal processing, electronics, oceanography, and noise and vibration control. Successful completion of the curriculum leads to award of the degree Master of Science in Engineering Acoustics, permits the officer to more knowledgeably address current and future military problems associated with antisubmarine warfare, and expands his base of professional knowledge and technical competence.

For officers who can report early, the curriculum is preceded by a non-credit, six-week refresher period which provides courses in basic mathematics (through calculus), physics, electrical engineering, and FORTRAN programming. (A non-credit course in refresher chemistry is also offered for those students who can academically accommodate this additional course.) The refresher period and the first three quarters of the nine-quarter curriculum are designed to provide a smooth transition from previous studies, and to provide the sound undergraduate background necessary for the subsequent advanced courses and thesis research. Portions of this undergraduate preparation may be validated by the better academically-prepared officer to permit study to a greater depth or breadth in graduate electives; or, subject to course scheduling limitations, shorten his time on board. Officers less academically prepared may first be enrolled in the Engineering Science Curriculum for one or more quarters to improve their probability for success in Underwater Physics Systems.

Early in the second year of instruction officers are evaluated for academic progress, accomplishments, and potential to complete the remaining portion of the curriculum. Those officers who have demonstrated a capability to satisfy academic requirements for the Master of Science degree will continue in the regular curriculum and select an area of specialized study for thesis research. The officers who are unable to continue in graduate-level work will normally be scheduled to complete their studies in seven, vice nine, quarters and will receive the degree, Bachelor of Science in Electrical Engineering, provided academic requirements are satisfied.

Naval officers of the unrestricted line graduating from this program are recommended for the subspecialty qualification code 8450P. Billet requirements for naval officers who have been assigned this code are contained in the *Annual Naval Officer Billet Summary.*

REPRESENTATIVE CURRICULUM (GROUP UX)

First Quarter

MA	1100	Calculus Review	4- 0
MA	2045	Introduction to Linear Algebra	3- 0
PH	1051	Review of Vector Mechanics and Optics	4- 2
EE	2101	Basic Circuit Theory	3- 2
			14- 4

Second Quarter

MA	2121	Differential Equations	4- 0
PH	2551	Thermodynamics	3- 0
EE	2211	Electronic Engineering Fundamentals I	4- 2
EE	2102	Circuit Analysis	4- 2
			15- 4

Third Quarter

MA	2161	Introduction to Mathematical Physics	4- 0
MA	2172	Complex Variables	4- 0
EE	2212	Electronic Engineering Fundamentals II	4- 3
EE	2103	Linear Systems Analysis	4- 2
			16- 5

Fourth Quarter

PH	3451	Fundamental Acoustics	4- 1
PH	2251	Waves and Particles	4- 2
PH	2351	Electromagnetism I	4- 0
EE	2114	Communication Theory I	4- 0
			16- 3

Fifth Quarter

PH	3452	Underwater Acoustics	4- 2
PH	3161	Physics of Underwater Vehicles	4- 1
PH	2352	Electromagnetism II	4- 0
PS	3411	Applied Probability Theory I	4- 1
PH	0499	Physics Colloquium	0- 1
			16- 5

Sixth Quarter

PH	4453	Propagation of Waves in Fluids	4- 0
PH	4454	Transducer Theory and Design	3- 2
PH	4455	Advanced Acoustics Laboratory	0- 3
EE	4571	Statistical Communication Theory	3- 2
PH	0499	Physics Colloquium	0- 1
			10- 8

Seventh Quarter

OC	3221	Descriptive Physical Oceanography	4- 0
EE	4451	Sonar Systems Engineering	3- 2
EE	4541	Signal Processing	3- 1
PH	0810	Thesis Research	0- 0
EE	0951	Seminar	0- 1
			10- 4

Eighth Quarter

OC	3261	Oceanography Factors in Underwater Sound	3- 0
ME	3500	Mechanical Vibrations and Noise Control	4- 0
PH	0810	Thesis Research	0- 0
OC	4900	Seminar in Oceanography	2- 0
			9- 0

Ninth Quarter

PH	4456	Seminar in Applications of Underwater Sound	3- 0
OS	3202	Methods of Operations Analysis/ Systems Analysis	4- 0
PH	0810	Thesis Research	0- 0
PH	0499	Physics Colloquium	0- 1
			7- 1

Campus scene with East Wing of Herrmann Hall in the background

CURRICULA CONDUCTED AT CIVILIAN UNIVERSITIES

Curriculum	*Number*	*Length*	*Institution*	*Curricular-Supervisory Control Authority*
Business Administration	810	2 yrs.	Cornell U.	NAVSUPSYSCOM
			Duke U.	NAVSUPSYSCOM
			U. of Mich.	NAVSUPSYSCOM
			U. of N. C.	NAVSUPSYSCOM
			U. of Pa.	NAVSUPSYSCOM
			U. of Va.	NAVSUPSYSCOM
Civil Engineering (Advanced)	470	1-2 yrs.	U. of Fla.*	NAVFACENGCOM
Typical Options:			Georgia Tech	NAVFACENGCOM
Structures			U. of Hawaii*	NAVFACENGCOM
Soil Mechanics			M. I. T.	NAVFACENGCOM
Sanitary Engineering			Purdue	NAVFACENGCOM
Waterfront Facilities			R. P. I.	NAVFACENGCOM
Facilities Planning			Texas A&M	NAVFACENGCOM
Construction Engineering			Tulane	NAVFACENGCOM
Civil Engineering Administration			U. of Cal. (Berkeley)	NAVFACENGCOM
Deep Ocean Construction Engineering			U. of Colo.	NAVFACENGCOM
			U. of Ill.	NAVFACENGCOM
			U. of Mich.	NAVFACENGCOM
			U. of Minn.	NAVFACENGCOM
			U. of Wash.	NAVFACENGCOM
Criminal Law	884	12 mos.	Geo. Wash. U.*	JAG
Electrical/Electronics Engineering (CEC)	471	12-18 mos.	Ga. I. T.	NAVFACENGCOM
			M. I. T.	NAVFACENGCOM
			Purdue	NAVFACENGCOM
			R. P. I.	NAVFACENGCOM
			U. of Cal. (Berkeley)	NAVFACENGCOM
			U. of Colo.	NAVFACENGCOM
			U. of Ill.	NAVFACENGCOM
			U. of Mich.	NAVFACENGCOM
Financial Management	812	1 yr.	Geo. Wash. U.*	NAVCOMP
Hydrographic Engineering (Geodesy)	475	2 yrs.	Ohio St. U.	OCEANAV
International Law	672	1 yr.	Geo. Wash. U.*	JAG
International Relations	671	1 yr.	various	BUPERS
Law (Army Judge Advocate Officers Advanced Course)	881	9 mos.	U. of Virginia	JAG
Management and Industrial Engineering	540	1 yr.	R. P. I.	NAVORD/ AIRSYSCOM
Mechanical Engineering (CEC)	473	1 yr.	Ga. I. T.	NAVFACENGCOM
			M. I. T.	NAVFACENGCOM
			Purdue	NAVFACENGCOM
			R. P. I.	NAVFACENGCOM
			U. of Cal. (Berkeley)	NAVFACENGCOM
			U. of Col.	NAVFACENGCOM
			U. of Ill.	NAVFACENGCOM
			U. of Mich.	NAVFACENGCOM
Naval Construction and Engineering	510	2/3 yrs.	M. I. T.	NAVSHIPSYSCOM
Nuclear Power Engineering (CEC)	572	18 mos.	Penn. State U.	NAVFACENGCOM

* *No NROTC unit at Institution.*

Nuclear Power Engineering (ED)	520	18 mos.	Penn. State U. ..... NAVFACENGCOM/ NAVSHIPS U. of Mich. ..... NAVSHIPSYSCOM
Ocean Law	883	12 mos.	U. of Miami (Florida)*..... JAG
Petroleum Administration and Management	880	1 yr.	SMU* ..... JAG
Petroleum Engineering (CEC)	630	1 yr. 6-12 mos.	U. of Texas ..... NAVFACENGCOM Industry
Petroleum Management	811	17 mos.	U. of Kansas ..... NAVSUPSYSCOM
Political Science	680	2 yrs.	U. of Wash. ..... OPNAV (OP-61) Various ..... OPNAV (OP-61)
Procurement Management	815	12 mos.	Geo. Wash. U. ..... NAVSUPSYSCOM
Public Relations	920	18 mos.	Various..... SHINFO
Religion	970	9 mos.	Various..... Chief of Chaplains
Retailing	830	1 yr.	Mich. State*..... NAVSUPSYSCOM
Subsistence Technology	860	1 yr.	Mich. State*..... NAVSUPSYSCOM
Systems Inventory Management	819	2 yrs.	Duke U. ..... NAVSUPSYSCOM U. of Mich..... NAVSUPSYSCOM
Taxation	882	1 yr.	Geo. Wash. Univ.*..... JAG
Transportation Management	813	1 yr.	Mich. State*..... NAVSUPSYSCOM

** No NROTC unit at Institution.*

These students are among the first group of Navy Warrant Officers to be accepted into the Baccalaureate program

CURRICULA AT OTHER UNIVERSITIES

The curricula listed in this section are conducted entirely at civilian educational institutions. Quotas for enrollment must be approved by the Chief of Naval Personnel and the Chief of Naval Operations. The table indicates the duration of each curriculum, the location, and the curricular supervisory control authority. Administration of officer students in connection with educational matters is exercised by the Superintendent, Naval Postgraduate School, through the Commanding Officer, NROTC Unit, or through the Senior Officer Student at those institutions where no NROTC Unit is established.

The information on courses is taken from college catalogues, but is subject to change from year to year. Changes depend on scheduling problems at the educational institutions and on the academic backgrounds of students. Further detailed information can be obtained from the catalogue of the institution concerned or by writing to the institution.

BUSINESS ADMINISTRATION CURRICULUM NUMBER 810

At: Cornell University

Duke University
University of Michigan
University of North Carolina
University of Pennsylvania
University of Virginia

OBJECTIVE — To provide officers graduate-level education in the fields of business administration.

CIVIL ENGINEERING (ADVANCED) CURRICULUM NUMBER 470

At: Georgia Institute of Technology

Massachusetts Institute of Technology
Purdue University
Rensselaer Polytechnic Institute
Texas A&M
Tulane University
University of California (Berkeley)
University of Colorado
University of Florida
University of Hawaii
Univeristy of Illinois
University of Michigan
University of Minnesota
University of Washington

OBJECTIVE — To educate officers for civil engineering duties. Options are available in all major fields of civil engineering. Typical options are: construction engineering, structures, soil mechanics, sanitary environmental engineering. Officers without prevous civil engineering education would undertake a two-year curriculum; officers holding a Bachelor of Civil Engineering degree would undertake a one-year to 18 month curriculum. This program is to qualify line officers (1100) for civil engineering duties and to provide advanced education for Civil Engineering Corps officers (5100).

Course length: One to two years

Degree attainable: Master of Science in Civil Engineering

ELECTRICAL/ELECTRONICS ENGINEERING (CEC) CURRICULUM NUMBER 471

At: Georgia Institute of Technology

Massachusetts Institute of Technology
Purdue University
Rensselaer Polytechnic Institute
University of California (Berkeley)
University of Colorado
University of Illinois
University of Michigan

OBJECTIVE — To provide advanced education for selected CEC officers in electrical engineering with emphasis on power plants and electrical power distribution. Other available options include: engineering systems and design, electromagnetic field theory, and electric utilities management.

Course length: 12 to 18 month

Degree attainable: Master of Science in Electrical Engineering

FINANCIAL MANAGEMENT CURRICULUM NUMBER 812

At: George Washington University

OBJECTIVE — To develop in officers of mature judgment and a broad background of professional experience the ability to interpret and analyze operational statistics for the purpose of developing standards of performance to provide a periodic review of operations in order to denote areas of management which are not meeting standards; to review budget estimates; and to plan programs for the improvement of management economy and efficiency through better organization, administration and procedures and better utilization of manpower, materials, facilities, funds, and time. The course is designed to give graduates a working knowledge of managerial controls adequate for assignment to financial management duties as a normal preparation for command and executive billets in the shore establishment.

Course length: One year

Degree attainable: Master of Science in Business Administration.

Typical Curriculum:

Undergraduate:

Survey of Accounting
Industrial and Governmental Economics
Statistical Decision Making
Management Communication

Graduates:
Cost Accounting
Managerial Accounting
Internal Control and Auditing
Survey of Data Processing
Financial Management
Seminar in Marketing
Business Organization and Management
Management Engineering
Readings and Conferences in Financial Management
Research Seminar
Research Seminar in Comptrollership
Human Relations in Administration
Governmental Budgeting

HYDROGRAPHIC ENGINEERING (GEODESY)
CURRICULUM NUMBER 475

At: Ohio State University

OBJECTIVE — To prepare officers for assignment to duties at the Oceanographic Office, on geodetic survey expeditions, and fleet staffs. The curriculum presents a fundamental theoretical knowledge of geodesy, cartography, and photogrammetry, particularly as applied to hydrographic surveying and the compilation and production of charts and maps.

Course length: Two years

Degree attainable: Master of Science in Geology

INTERNATIONAL LAW
CURRICULUM NUMBER 672

At: George Washington University

OBJECTIVE — To prepare Judge Advocate General Corps Officers (2500) for duties involving problems of international law. The course encompasses international law and agreements including the law of air, sea, and space legal aspects of U. S. foreign relations, negotiations, and legal regulation of international coercion. A thesis on a topic of significant international law interest is required. In addition, certain studies of a geographic area selected by the student will be conducted.

Course length: One year

Degree attainable: Master of Laws

INTERNATIONAL RELATIONS
CURRICULUM NUMBER 671

At: Various universities

OBJECTIVE — To provide a broad understanding of the forces and factors in international relations to equip officers to meet responsibilities involving knowledge of the international situation, including awareness of the role of sea power in world affairs.

Course length: One year

Degree attainable: Master of Arts

LAW
CURRICULUM NUMBER 881

(Army Judge Advocate Officers Advanced Course)

At: University of Virginia

OBJECTIVE — To prepare more experienced Judge Advocate General Corps Officers (2500) for advanced staff responsibilities in the various legal fields. The course encompasses all branches of military law with emphasis on the administration of the Uniform Code of Military Justic, military affairs, civil affairs arising out of the operation of or litigation of military law including the laws of war, procurement and contract law, and legal assistance to military personnel.

Course length: Nine months

MANAGEMENT AND INDUSTRIAL ENGINEERING
CURRICULUM NUMBER 540

At: Rensselaer Polytechnic Institute

OBJECTIVE — To prepare selected officers for managerial and industrial engineering billets in the Navy's industrial organization. The curriculum majors in industrial engineering and its application to managerial problems.

Course length: One year

Degree attainable: Master of Science in Management Engineering

Typical Curriculum:

Summer:
Review of Quantitative Methods
Statistical Methods
Law in Management and Engineering
Data Processing

Fall:
Cost Finding and Control
New Product Problems or
Organization and Management of Marketing
Organization Planning and Development
Industrial Relations
Production Management I

Spring:
Administrative Practice and Behavior
Financial Planning and Control
Seminar in Management
Production Management II
Analytical Methods in Management

MECHANICAL ENGINEERING (CEC)
CURRICULUM NUMBER 473

At: Georgia Institute of Technology
Massachusetts Institute of Technology
Purdue University
Rensselaer Polytechnic Institute
University of California (Berkeley)
University of Colorado
University of Illinois
University of Michigan

OBJECTIVE — To provide advanced education for selected CEC officers in mechanical engineering with emphasis on power plants, heating and ventilation, and utilities management.

Course length: One year

Degree attainable: Master of Science in Mechanical Engineering

NAVAL ENGINEERING
CURRICULUM NUMBER 510

At: Massachusetts Institute of Technology

OBJECTIVE — To prepare officers to engage in Ship Systems Engineering from the concept of the "whole ship." The curricula centers around the broad field of Naval Architecture supplemented with options in the following areas:

Structures

Hydrodynamics and Ship Control

Ocean Engineering (General)

Ocean Engineering (Underwater Sensing and Communications)

Mechanical Engineering (Control Systems or Propulsion)

Nuclear Engineering

Electrical Engineering (Above Water Sensing and Communications or Underwater Sensing and Communications or Power Generation and Transmission)

An additional option available for qualified students involves studies in the Sloan School of Management in a "Dual Masters Program."

Selection of options is made after completion of the initial summer term (students report in June for this program). Exceptional students are encouraged to pursue advanced work to the doctoral level if career consideration permit.

For the third summer a "Professional Summer" is planned where rigorous advanced technology material will be offered to students attending this program. This material (which will be classified if necessary) will insure the relevancy of the program to the Naval Officer's professional involvement in highly sophisticated total ship systems.

Course length: Two or Three years

Degreee attainable: Naval Engineer with a lesser included degree of Master of Science in that option selected by the student. Those students who choose the Dual Engineering/Management program receive two M. S. degrees, one in Naval Architecture and one in Management. Some students, electing only a two year program, can earn two technical M.S. degrees, one in Naval Architecture and one in the option selected by the student.

NUCLEAR POWER ENGINEERING (CEC)
CURRICULUM NUMBER 572

At: The Pennsylvania State University

OBJECTIVE — To provide education for selected CEC officers in nuclear power engineering. Graduates of this curriculum will normally be assigned duties in the shore nuclear power program under the technical direction of the NAVFACENGCOM.

Course length: 18 months

Degree attainable: Master of Science

PETROLEUM
ADMINISTRATION AND MANAGEMENT
(Gas, Oil and Water Rights)
CURRICULUM NUMBER 880

At: Southern Methodist University

OBJECTIVE — To provide Judge Advocate General Corps Officers (2500) with a study of government regulations in oil and gas law taxation problems, and special research and study of the evolution of law concerning water rights, current law affecting these rights, and technical prolems attendant thereto so as to prepare them for assignment to billets concerned with the administration and management of the Naval Petroleum and Oil Shale Reserves and with the special problems in the field of water rights.

Course length: One year

Degree attainable: Master of Laws in Oil and Gas

PETROLEUM ENGINEERING (CEC)
CURRICULUM NUMBER 630

At: University of Texas
and in the petroleum industry

OBJECTIVE — To prepare selected CEC officers for assignments to duty involving the administration and operations of Naval Petroleum and Oil Shale Reserves. The curriculum provides the student with a knowledge of petroleum development and production procedures, geology, petroleum economics and reservoir engineering.

Course length: One year of academic work followed by 6 months in the field with a major oil company

Degree attainable: Master of Science in Petroleum Engineering

PETROLEUM MANAGEMENT
CURRICULUM NUMBER 811

At: University of Kansas

OBJECTIVE — To provide officers of the Supply Corps graduate level education in the functional proficiency field of petroleum management and administration.

Course length: Seventeen months

Degree attainable: Master of Science

Typical Curriculum:

Fall:
Quantitative Analysis I
Material and Energy
Development of Oil and Gas Lands
Theoretical Principles of Petroleum Production

Spring:
Quantitative Analysis II
Field Practice in Natural Gas
Appraisal of Oil and Gas Properties
Research

Summer:
Personnel Management
Legal Aspects of Business Research

Fall:
Petroleum Management Research

POLITICAL SCIENCE
CURRICULUM NUMBER 680

At: University of Washington
Various other universities

OBJECTIVE — To equip a limited number of intellectually mature officers with a broad professional background in international relations in order that they may provide professional advice and assistance in the formulation and execution of national policy. Studies should be specifically directed toward obtaining sound knowledge and understanding in:
(1) The theory of international politics, economics, law, and U. S. diplomatic history.
(2) The politics, geography, and history of one of the following regions of the world: Europe, Asia, Africa, Western Hemisphere.
(3) The history, role and importance of worldwide and regional international organizations.
(4) Development and execution of U. S. political, military and economics policy as it pertains to U. S. foreign relations.

Course length: Two years

Degree attainable: Master of Arts

PROCUREMENT MANAGEMENT
CURRICULUM NUMBER 815

At: George Washington University

OBJECTIVE — To provide officers of the Supply Corps graduate level education in the field of military and commercial procurement:

Course length: One year

Degree attainable: Master of Business Administration

PUBLIC RELATIONS
CURRICULUM NUMBER 920

At: Various universities

OBJECTIVE — To provide advanced qualifications of officers in the field of public relations. Officers selected for program must have previous education or experience in public information and public relations. This curriculum will be made up from regular course offerings of the university and will be based on an officer student's background and particular interest within the curricular area.

Course length: One year to 18 months

Degree attainable: Master of Arts in Public Relations

RELIGION
CURRICULUM NUMBER 970

At: Various universities

OBJECTIVE — To broaden the education of officer students in such fields as psychology, theology, homiletics, and counseling, hospital ministry and education.

Course length: 9 months

RETAILING
CURRICULUM NUMBER 830

At: Michigan State University

OBJECTIVE — To provide officers of the Supply Corps with graduate level education in the functional proficiency field of retailing. Emphasis is placed on consumer markets, sales promotion, merchandise and merchandising, and the management functions associated therewith.

Course length: One year

Degree attainable: Master of Business Administration

SUBSISTENCE TECHNOLOGY
CURRICULUM NUMBER 860

At: Michigan State University

OBJECTIVE — To provide officers of the Supply Corps with graduate level education in the field of food management.

Course length: One year

Degree attainable: Master of Business Administration

SYSTEMS INVENTORY MANAGEMENT
CURRICULUM NUMBER 819

At: Duke University
University of Michigan

OBJECTIVE — To provide officers of the Supply Corps with a well-grounded education at the graduate level in the scientific methods of inventory management.

Course length: Two years

Degree attainable: Master of Business Administration

TRANSPORTATION MANAGEMENT
CURRICULUM NUMBER 813

At: Michigan State University

OBJECTIVE — To provide officers of the Supply Corps with graduate level education in the functional proficiency field of transportation management.

Course length: One year

Degree attainable: Master of Business Administration

Typical Curriculum:

Basic Accounting II
Financial Management
Basic Marketing
Basic Statistics I
Accounting for Financial and Profit Management II
Problems in Business Economics
Basic Statistics II
Transportation Policy
Accounting for Financial and Profit Management III
Human Problems in Administration
Social Problems in Administration
Marketing Management
Transportation Seminar

R/V Acania

Rear Admiral A. Scott Goodfellow discusses new features of the School's research vessel ACANIA with Rear Admiral Malcolm E. Garrison, USN (Ret), a deputy in the Office of the Oceanographer of the Navy (center), and Dr. Dale F. Leipper, the School's Oceanography Department chairman

ACADEMIC DEPARTMENTS and COURSE DESCRIPTIONS

DEPARTMENT OF AERONAUTICS

RICHARD WILLIAM BELL, Professor of Aeronautics; Chairman (1951)*; A.B., Oberlin College, 1939; Ae.E., California Institute of Technology, 1941; Ph.D., 1958.

ROBERT EDWIN BALL, Associate Professor of Aeronautics (1967); B.S. in C.E., Northwestern Univ., 1958; M.S., 1959; Ph.D., 1962.

MILTON HAROLD BANK, II, Assistant Professor of Aeronautics (1971); B.S., Naval Academy, 1957; B.S.A.E., Naval Postgraduate School, 1964; Engr., Stanford, 1967; M.S., Georgia Institute of Technology, 1970; Ph.D., 1971.

OSCAR BIBLARZ, Assistant Professor of Aeronautics (1968), B.S., Univ. of California at Los Angeles, 1959; M.S., 1963; Ph.D., Stanford Univ., 1968.

DANIEL JOSEPH COLLINS, Professor of Aeronautics (1967); B.A., Lehigh Univ., 1954; M.S. in M.E., California Institute of Technology, 1955; Ph.D., 1961.

ALLEN EUGENE FUHS, Professor of Aeronautics (1970); B.S.M.E., Univ. of New Mexico, 1951; M.S.M.E., California Institute of Technology, 1955; Ph.D., 1958.

THEODORE HENRY GAWAIN, Professor of Aeronautics (1951); B.S., Univ. of Pennsylvania, 1940; D.Sc., Massachusetts Institute of Technology, 1944.

RONALD ANDREW HESS, Assistant Professor of Aeronautics (1970); B.S.A.E., Univ. of Cincinnati, 1965; M.S.A.E., 1967; Ph.D., 1970

GUSTAVE JOHN HOKENSON, Lieutenant (junior grade), U S. Naval Reserve; Assistant Professor of Aeronautics (1970); B.S., Univ. of Maryland, 1966; M.S., 1968, Ph.D., 1970.

CHARLES HORACE KAHR, JR., Professor of Aeronautics (1947); B.S., Univ. of Michigan, 1944; M.S., 1945.

DONALD MERRILL LAYTON, Associate Professor of Aeronautics (1965); B.S., Naval Academy, 1945; B.S.A.E., Naval Postgraduate School, 1953; M.S. in A.E., Princeton Univ., 1954; M.S., Naval Postgraduate School, 1968.

GERALD HERBERT LINDSEY, Associate Professor of Aeronautics (1965); B.E.S. in M.E., Brigham Ycung Univ. 1960; M.S., 1962; Ph.D., California Institute of Technology, 1966.

JAMES AVERY MILLER, Associate Professor of Aeronautics (1963); B.S. in M.E., Stanford Univ., 1955; M.S. in M.E., 1957; Ph.D., Illinois Institute of Technology, 1963.

DAVID WILLIS NETZER, Associate Professor of Aeronautics, (1968); B.S.M.E., Virginia Polytechnic Institute, 1960; M.S.M.E., Purdue Univ. 1962; Ph.D., 1968.

MAX FRANZ PLATZER, Associate Professor of Aeronautics (1970); Dipl Ing., Tech. Univ. of Vienna, Austria ,1957; Dr. Techn. Sci., 1964.

HOWARD LEON POWER, Assistant Professor of Aeronautics (1971); B.S.A.E., Iowa State Univ., 1963; M.S.A.E., Stanford Univ. 1967; Ph.D., Iowa State Univ. 1971.

MICHAEL H. REDLIN, Lieutenant (junior grade), U. S. Naval Reserve; Assistant Professor of Aeronautics (1970); B.S., Cornell Univ., 1967; Ph.D., (pending).

LOUIS VINCENT SCHMIDT, Professor of Aeronautics, (1964); B.S., California Institute of Technology, 1946; M.S., 1948; Ae.E., 1950; Ph.D., 1963.

MICHAEL HANS VAVRA, Distinguished Professor of Aeronautics, (1947); Dipl. Ing., Swiss Federal Institute of Technology, 1934; Ph.D., Univ. of Vienna, 1958.

ROBERT DIEFENDORF ZUCKER, Associate Professor of Aeronautics (1965); B.S. in M.E., Massachusetts Institute of Technology, 1946; M.M.E., Univ. of Louisville, 1958; Ph.D., Univ. of Arizona, 1966.

EMERITUS FACULTY

WENDELL MAROIS COATES, Distinguished Professor Emeritus (1931); A.B., Williams College, 1919; M.S., Univ. of Michigan, 1923; D.Sc., 1929.

ULRICH HAUPT, Associate Professor Emeritus (1954); Dipl. Ing., Institute of Technology, Darmstadt, 1934.

GEORGE JUDSON HIGGINS, Professor Emeritus (1942); B.S., in Eng. (Ae.E.), Univ. of Michigan, 1923; Ae.E., 1934.

HENRY LEBRECHT KOHLER, Professor Emeritus (1943); B.S., in M.E., Univ. of Illinois, 1929; M.S. in M.E., Yale Univ., 1930; M.E., 1931.

** The year of joining the Postgraduate School Faculty is indicated in parentheses.*

AERONAUTICAL LABORATORIES

Seven major laboratory divisions facilitate instructional and research programs in subsonic aerodynamics, structural test, rocket propulsion, cascades and turbomachinery, flight mechanics, gasdynamics, and jet engines.

The subsonic aerodynamics laboratory consists of two low-speed continuous flow wind tunnels and a large continuous flow smoke tunnel. Standard techniques are used in the 32x45 inch and 42x60 inch wind tunnels to measure quantities such as steady and unsteady velocity pressure, loads, and hinge moments to study basic fluid flows about bodies, stability and control of aerodynamic vehicles, and unsteady flows about bluff bodies and lifting surfaces. The three-dimensional smoke tunnel has a basic test section of 5x5x12 feet expandable to 15x15x12 feet. The smoke filaments are pulsed and may be studied stroboscopically and photographed to define the flow field in a variety of applications.

The structural test laboratory contains testing machines with varying capacities up to 300,000 pounds for demonstration and analysis of relatively small structures. Large aircraft components such as a P2V wing and a F8U-2 wing are accommodated on the special loading floor of the laboratory where

static and vibration tests are carried out. An adjacent strain-gage and instrumentation laboratory is employed for instruction in structural testing techniques. A well equipped dynamics laboratory contains shaker tables, analog computers, and associated electronic instrumentation. Class work and research are conducted in various areas of applied mechanics such as non-linear structural dynamics, elastic wave propagation, and dynamic transfer function evaluation.

The rocket laboratory consists of an instrumented control room, a propellant chemistry laboratory, a high pressure air facility which provides dry, filtered air to 3500 psia, and three test cells for operation of solid, liquid, gaseous, and hybrid rocket motors. Tests may be conducted on a large centrifuge to pressures of 1500 psia, and to accelerations of 2000g. A photographically equipped centrifuge, a bi-phase rocket motor and a gas chromatograph are also in operation.

The advanced facilities of the cascade and turbomachinery laboratories are distributed in three buildings, one of which provides low speed tests with rectilinear cascades of large dimensions. The source of air is a 700 HP fan, either to draw or to blow air through the test items, which delivers about 100,000 cfm of air at a pressure difference of about 40 inches of water. This source can be used also to perform model tests with flow channels, inlet and discharge casings, scrolls and diffusors. The special rectilinear cascade test rig is equipped with semi-automatic instrumentation; data are obtained with an electronic logging system for data reduction on digital computers. A second building houses a centrifugal compressor test rig, instrumented for conventional performance measurements and for special investigations of three-dimensional flows about both the stationary and the rotating vanes. The third building is used for high speed tests, in three test cells, monitored from a central control room. A 1250 HP variable-speed axial-flow compressor, which is instrumented also for interstage measurements, produces high pressure air either for turbine testing, or to drive test compressors, pumps, and other test items. This building contains many different types of turbomachinery including a 3-stage axial flow compressor, a transonic axial test rig with vacuum exhauster system, a radial turbine test rig, a transonic compressor test rig, a critical shaft speed test bench, a 3-stage centrifugal compressor and a radial compressor test rig. An adjacent control room contains a complete data acquisition system. Adjacent to the third building is a hotspin test unit, where disks and propellers can be rotated at speeds up to 50,000 rpm. Heating and cooling elements make is possible to impose radial temperature gradients. Instrumentation is provided to conduct stress work, with strain gauges, up to 27,000 rpm and a maximum temperatures of 1800°F. Also available are a probe calibration tunnel with annular cross section for the calibration of pressure and hot-wire probes and a two phase flow test rig for direct measurement of wall shear stress.

The flight mechanics laboratory utilizes, for classroom and research projects, a jet instrument trainer which has been modified into a cockpit simulator suitable for use in problems of variable stability. This simulator is used in conjunction with the electrical Engineering Department's hybrid computer. An additional simulator has been constructed and is being utilized with the Aeronautics Department's analog computer to study pilot reaction to rigid and movable control sticks.

The gas dynamics laboratory includes a blow-down supersonic wind tunnel having a 4x4 inch test section and an operating Mach number range from 1.4 to 4. Instruments associated with this facility include 6" and 9" Mach Zehnder interferometers and 5" and 9" Schlieren systems for flow observations. A ruby Q-switched holographic laser is also available for flow field visualization. A cold-driven, three inch, double-diaphragm shock tube has been constructed for measurement of the thermal conductivity of noble gases and for the study of vibration relaxation, gas dissociation, and ionization. He-Ne, Argon, and CO_2 lasers are utilized in various experiments including a Gaertner-Jeong holography system. An electro-hydrodynamic research facility in which electric power generation and turbulence are being studied, and a coaxial plasma accelerator, have recently been completed. Another facility is an open circuit oscillating flow wind tunnel, two feet square and 18 feet long, in which nearly sinusoidal perturbations may be superimposed on the free stream flow by means of a series of four synchronously driven rotating shutters; frequencies of 0.1 to 250 cps may be obtained. Principal instrumentation available for this tunnel is a ten channel constant-temperature linearized hot-wire anemometer.

The jet engine laboratory incorporates two complete test cells, one for testing turboprop engines and the other for testing turbojet engines. They are operated from an adjacent control room. A separate engine maintenance shop is located adjacent to the test cells.

In addition, a computation laboratory has been set up to facilitate analytical solutions of classroom and research problems. A remote console for the Naval Postgraduate School IBM 360-67 computer is available, together with numerous electronic desk calculators.

REPARTMENTAL REQUIREMENTS FOR DEGREES IN AERONAUTICAL ENGINEERING

The following are academic requirements for the award of these degrees as determined by the Aeronautics Department. In addition the general minimum requirements as determined by the Academic Council must also be satisfied.

The entrance requirement for study in the Aeronautics Department generally is a baccalaureate in engineering earned with above-average academic performance. This requirement can sometimes be waived for students who have shown distinctly superior ability in backgrounds other than engineering but who have had adequate coverage in the basic physical and mathematical sciences. All entrants must obtain the approval of the Chairman, Department of Aeronautics.

Students who have not majored in Aeronautics, or who have experienced a significant lapse in continuity with previous academic work, initially will take a Core of courses in aeronautical engineering and mathematics at the upper division level. The Core, consisting of 2000 and 3000 level courses, extends

through the first three academic quarters and constitutes a portion of the coursework for degrees in Aeronautics.

Final approval of programs leading to degrees in Aeronautical Engineering is to be obtained from the Chairman, Department of Aeronautics.

MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

Upon completing the Core, students may be selected on the basis of academic performance for the degree program leading to the Master of Science in Aeronautical Engineering. However, students who have recently earned a degree with major in Aeronautics may apply for admission directly to the graduate program.

This degree requires a minimum of 36 quarter hours of graduate course credits beyond the Core, which will include a minimum of 20 quarter hours at the 4000 level, and a minimum 10 quarter hours in courses outside the Aeronautics Department. An acceptable thesis is required for the degree unless waived by the Chairman, Department of Aeronautics, in which case 10 quarter hours of 4000 level courses will be required in addition to those specified above, increasing the total requirement to 46 quarter hours of graduate-level credits.

AERONAUTICAL ENGINEER

After having been selected to work toward the degree Master of Science in Aeronautical Engineering, a student may be admitted to work for the degree Aeronautical Engineer. Selection to this degree program shall be limited to those students who, in the opinion of the faculty, have the potential to conduct the required research.

This degree requires 72 quarter hours of graduate course credits beyond the Core, which will include a minimum of 40 quarter hours at the 4000 level, and a minimum of 20 quarter hours in courses outside the Aeronautics Department. An acceptable thesis is required for the degree.

Students admitted to work for the degree Aeronautical Engineer may be satisfying requirements for the Master of Science degree concurrently. The Master of Science in Aeronautical Engineering may be conferred at the time of completion of the requirements for that degree.

DOCTOR OF PHILSOSPHY

Entrance into the doctorate program may be requested by officers currently enrolled who have completed the Aero Common Core with a sufficiently high standing. An oral screening examination will be scheduled by the Department Chairman, to be conducted by members of the Department whom he selects. Eligibility in the program must be established by the petitioner's performance in this screening examination, before the additional time required of his assignment to the School can be determined. Thereafter the requirements to be met are as outlined under the section on general information at the front of the Catalogue. Programs are currently offered in gasdynamics, flight structures, flight dynamics, propulsion, and aerospace physics.

The Department also accepts officer students selected in the Navywide Doctoral Study Program, and civilian students selected in the School's Cooperative Doctoral Program with the Navy and other Defense Laboratories. These students will have had prior Master's degrees in science or engineering. They must also further demonstrate their eligibility for the Aeronautics doctorate program by satisfactory performance in an oral screening examination.

NEW OPERATIONAL GRADING SYSTEM OF THE DEPARTMENT OF AERONAUTICS

The Department of Aeronautics is currently testing and evaluating a new grading system. The new grade designations and their meanings are summarized below:

Symbol	*Meaning*
H—Honors	Confers credit toward graduate degree with honors, or any lesser degree. For an undergraduate, implies a strong recommendation for admission to graduate standing.
G—Graduate	Confers credit toward a graduate or baccalaureate degree. For an undergraduate, implies a recommendation for admission to graduate standing.
S—Satisfactory	Confers credit toward a baccalaureate degree but not toward a graduate degree. This grade is not used in 4XXX level courses. For an undergraduate, implies a recommendation against admission to graduate standing.
I—Incomplete	Denotes incomplete or deficient work. Confers no degree credit. Student has one year to remedy deficiency whereupon the grade of I is superseded by the grade earned, with corresponding degree credit.
N—No Credit	Confers no degree credit for the course. The effect on the student's subsequent program shall be determined in consultation with the Chairman, Department of Aeronautics. Course may be repeated for credit if prior approval be received from Chairman.

The grades are operational rather than numerical in character and indicate the level of degree credit granted for each course. They also provide suitable recommendations, where applicable, pertaining to subsequent admission to graduate standing. No overall grade point average is computed under this system. The decision to grant or deny degree credit is made individually for each course by the instructor involved. The degree is earned when the student has accumulated the necessary credits in various categories, as specified in the relevant degree require-

ments, and has completed an acceptable thesis. A noteworthy feature of the new system is the I grade, which provides the opportunity and incentive for remedial study by the student whose work shows areas of weakness; the emphasis here is on corrective rather than on punitive action.

The new system also requires that each student be supplied at the beginning of each course with a detailed specification of behavioral objectives for the course. These objectives indicate the observable performance he must demonstrate in order to qualify for the various possible grades in the course.

GENERAL PREREQUISITE REQUIREMENTS

Unless otherwise stated the common core of courses listed on page 29 for the first three quarters, or equivalent preparation to be approved by the Chairman, Department of Aeronautics, is prerequisite to all other aeronautics courses. It is also advisable that the review courses AE 0110 and MA 0112 precede the common core of courses.

AERONAUTICS

AE 0010 AERONAUTICAL ENGINEERING SEMINAR (0-2). Oral presentations of material not covered in formal courses. Topics cover a wide spectrum of subjects ranging from reports of current research to survey treatments of fields of scientific and engineering interest.

AE 0110 REVIEW OF STATICS AND ELEMENTARY STRENGTH OF MATERIALS (4-4). A special six-week course to review the principles of statics of rigid bodies and pin-connected trusses; stress, strain and Hooke's law; simple tension, compression, and shear. Properties of areas and volumes, and of materials. TEXT: Beer and Johnson, *Mechanics for Engineers, Statics.*

AE 0610 ANALOG COMPUTERS (0-2). A six-week course covering the theory and operation of analog computers. Operational amplifiers and analog circuitry. Algebraic operations, integration, time scaling and amplitude scaling. Typical applications in Aeronautics. TEXT: Instructor's Notes.

AE 0810 THESIS RESEARCH (0-0). Every student conducting thesis research will enroll in this course.

Upper Division Courses

(Note Common Core listing, p. 29)

AE 2021 AERO-STRUCTURES I (3-2). Multi-dimensional concepts of stress and strain, mechanical behavior of materials, structural idealization, bending and torsional stress analysis of typical aero-structural components. TEXT: Popov, *Introduction to Mechanics of Solids.*

AE 2022 AERO-STRUCTURES II (3-2). Introduction to energy methods, deflection analysis of aero-structures, statically indeterminate structures, and stability of beam-columns. TEXT: Instructor's Notes. PREREQUISITE: AE 2021.

AE 2031 VEHICLE AERODYNAMICS I (3-2). Model atmospheres; defined airspeeds and altitudes; aircraft vehicle performance including range, endurance, climb rate, take-off and landing. TEXT: Dommasch, Sherby & Connally, *Airplane Aerodynamics.*

AE 2032 VEHICLE AERODYNAMICS II (3-2). Elements of two-dimensional flow, thin airfoil theory, finite wing theory, static aeroelastic effects on wing loads. TEXT: Houghton and Brock, *Aerodynamics for Engineering Students.* PREREQUISITE: AE 2041.

AE 2041 BASIC FLUID MECHANICS (3-2). Elementary fluid mechanics. Properties of fluids, fluid statics, dimensional analysis and dynamic similarity; principles of continuity, energy, and momentum; losses in internal flow systems, laminar and turbulent flow regimes; flow measurement; introduction to boundary layers, pressure and friction drag. TEXT: Pao, *Fluid Mechanics.*

AE 2042 ENGINEERING THERMODYNAMICS (3-2). Fundamental concepts of thermodynamics. Equations of state, properties of pure substances, property relations; first and second laws of thermodynamics, entropy, irreversibility, availability; non-reactive mixtures; power cycle analysis. TEXT: Van Wylen and Sonntag, *Introduction to Thermodynamics; Classical and Statistical.*

AE 2801 INTRODUCTION TO AERO-LABORATORIES (0-3). An introduction to modern experimental techniques and instrumentation. Lectures, demonstrations and simple experiments in the use of sensing devices, intermediate components, readout and recording devices. Evaluation of errors, data reduction and analysis, report writing. Familiarization with aeronautical engineering facilities. TEXT: Holman, *Experimental Methods for Engineers.*

Upper Division or Graduate Courses

(Note section on general prerequisite requirements)

AE 3015 ENGINEERING DYNAMICS (3-2). Lagrange's equations for particle systems; rigid body dynamics and the inertia tensor; Euler equations. Introduction to vibration theory and the eigenvalue problem. TEXT: Pestel and Thompson, *Dynamics.*

AE 3033 VEHICLE AERODYNAMICS III (3-2). Principles of longitudinal, lateral, and directional static stability and control of aircraft; single degree of freedom analysis; dynamic stability concepts of aircraft, analog computer techniques. TEXT: Etkin, *Dynamics of Flight.*

AE 3043 FUNDAMENTAL CONCEPTS OF GASDYNAMICS (3-2). The dynamics and thermodynamics of compressible fluid flow. One-dimensional isentropic flow, normal and oblique shocks, Prandtl-Meyer flow; Fanno and Rayleigh flows. Applications to aeronautics. TEXT: John, *Gas Dynamics.*

AE 3331 FLIGHT EVALUATION TECHNIQUES I (2-0). Quantitative and qualitative techniques for evaluation of aircraft performance in flight. Data acquisition systems. Course work supported by AE 3831, a flying laboratory in Naval Aircraft. TEXTS: NATC Performance Test Manual and NATC Engine Performance Manual.

AE 3332 FLIGHT EVALUATION TECHNIQUES II (2-0). Techniques for evaluation of aircraft static and dynamic stability and control characteristics. Course work supported by AE 3832, a flying laboratory in Naval Aircraft. TEXTS: NATC Stability and Control Manual and Mil Spec Mil-F-8785A.

AE 3811 SOLID MECHANICS LABORATORY (0-3). Selected experiments in the areas of aero-structures and dynamics. TEXT: Instructor's Notes. PREREQUISITES: AE 2022, AE 3015 concurrently.

AE 3831 FLIGHT EVALUATION TECHNIQUES LAB I (0-4). In-flight investigations of the technical aerodynamics of aircraft pertinent to performance evaluation. PREREQUISITE: AE 3331 concurrently.

AE 3832 FLIGHT EVALUATION TECHNIQUES LAB II (0-4). In-flight investigations of the technical aerodynamics of aircraft pertinent to static and dynamic stability and control. PREREQUISITE: AE 3332 concurrently.

AE 3851 GASDYNAMICS LABORATORY (0-3). Selected experiments in the areas of subsonic and supersonic compressible fluid flow. TEXT: Instructor's Notes. PREREQUISITES: AE 2032, 3043.

AE 3900 SPECIAL TOPICS IN AERONAUTICS (2-0 to 5-0). Directed graduate study in laboratory research. Course may be repeated for additional credit if topic changes. PREREQUISITE: Consent of Department Chairman.

Graduate Courses

(Note section on general prerequisite requirements)

AE 4101 FLIGHT VEHICLE STRUCTURAL ANALYSIS I (3-2). Theory of plates and shell structures as applied to aircraft and space-vehicles. Classical theory; analytical methods of analysis; numerical methods of analysis; stability; design considerations. TEXT: Wang, *Applied Elasticity.*

AE 4102 FLIGHT VEHICLE STRUCTURAL ANALYSIS II (3-2). Matrix methods of structural analysis of aircraft and space-vehicle structures. Structural idealization; stiffness and flexibility properties of structural elements; matrix displacement and matrix force methods; structural partitioning and analysis of substructures. TEXT: Martin, *Introduction to Matrix Methods of Structural Analysis.*

AE 4131 SOLID MECHANICS FOR AERONAUTICAL ENGINEERS I (4-0). An overview of elastic analysis of continua beginning with the formulation of the three dimensional field equations of elasticity and continuing with methods of stress analysis, including classical analytical methods, experimental methods and numerical methods. Theories of failure are also presented by which the stress analysis can be used to assess ultimate structural integrity. TEXT: Wang, *Applied Elasticity.*

AE 4132 SOLID MECHANICS FOR AERONAUTICAL ENGINEERS II (4-0). An in-depth treatment of current methods of analysis applicable to aerospace structures, which include two-dimensional solutions by means of complex variables, photoelasticity and finite elements. TEXT: Wang, *Applied Elasticity.* PREREQUISITE: AE 4131.

AE 4139 SPECIAL TOPICS IN SOLID MECHANICS (4-0). Selected advanced coverage from topics including: plasticity, viscoelasticity, general stability, thermoelasticity, nonlinear elasticity, wave propagation, fracture mechanics. May be repeated for credit with a different topic. PREREQUISITE: Consent of Department Chairman.

AE 4271 DESIGN PROBLEMS IN AERONAUTICS I (3-3). A complex engineering problem in the field of flight vehicles is presented for solution by systems-oriented methods, with the primary purpose of developing basic understanding for the design process. Integration of various disciplines, evaluation of airworthiness requirements, real-life complexities, and team work with clearly assigned responsibilities are emphasized. PREREQUISITE: Consent of Department Chairman.

AE 4272 DESIGN PROBLEMS IN AERONAUTICS II (3-3). Continuation of AE 4271.

AE 4301 FLIGHT VEHICLE RESPONSE (3-2). Topics in advanced stability and control of flight vehicles including the effects of cross-coupling, aeroelasticity, and reentry dynamics. TEXT: Etkin, *Dynamics of Flight, Stability and Control.*

AE 4302 LOW SPEED VEHICLE AERODYNAMICS (3-2). Topics in the stability, control and performance characteristics of low-speed aircraft; ground effect phenomena; VTOL, STOL and rotary wing aircraft, air cushion and compound vehicles. TEXT: Gessow and Meyers, *Aerodynamics of the Helicopter.*

AE 4316 STRUCTURAL DYNAMICS (3-2). Response of discrete and continuous systems of deterministic excitations, estimation methods for solving the eigenvalue problem; wave propagation in solids and fluids; response to stochastic processes. TEXT: Meirovitch, *Analytical Methods in Vibrations.*

AE 4317 AEROELASTICITY (4-0). Static aeroelasticity problems in aircraft; non-stationary airfoil theory; strip and lifting surface concepts. Application to the flutter problem. Transient loads, gusts, buffet, and stall flutter. TEXTS: Abramson, *Introduction to the Dynamics of Airplanes;* and Instructor's Notes. PREREQUISITE: AE 4316.

AE 4341 GUIDANCE AND CONTROL FOR AEROSPACE SYSTEMS I (3-2). Power controls and stability augmentation; component and pilot transfer functions; applications of frequency response techniques; systems analysis of aircraft controls; cross-coupling; performance specifications and response shaping. TEXT: Instructor's Notes.

AE 4342 GUIDANCE AND CONTROL FOR AEROSPACE SYSTEMS II (3-2). Vehicle dynamics and interaction with augmentation devices and automatic controls; automatic power compensation; time-modulated aerodynamic controls; missile control; terrain following. Random processes and auto-correlation functions; adaptive control systems; power spectral densities. Optimum design. TEXT: Instructor's Notes. PREREQUISITE: AE 4341.

AE 4401 ADVANCED THERMODYNAMICS (3-2). Reactive mixtures, kinetic theory, transport phenomena, quantum statistics; partition functions, thermodynamic properties. TEXTS: Vincenti, *Introduction to Physical Gas Dynamics;* and Instructor's Notes.

AE 4402 COMBUSTION (3-2). Formation of molecules and chemical bonds; classical chemical kinetics, rate laws; premixed systems, detonations and deflagrations; diffusion flames; ignition theory. TEXTS: Denbigh, *Principles of Chemical Equilibrium;* and Pratt, *Gas Kinetics.* PREREQUISITE: AE 4401.

AE 4409 ADVANCED TOPICS IN COMBUSTION (3-2). Chemical reactions in flow systems, solid propellant combustion, liquid droplet combustion, supercritical combusion. PREREQUISITE: AE 4402.

AE 4431 AEROTHERMODYNAMICS OF TURBOMACHINES (4-0). Application of fundamental laws of fluid dynamics and thermodynamics to the analysis of flows in turbomachines. TEXT: Vavra, *Aerothermodynamics and Flow in Turbomachines.*

AE 4432 ADVANCED THEORY OF TURBOMACHINES (4-0). Advanced theory and methods for design and performance prediction of turbomachines. TEXT: Vavra, *Aerothermodynamics and Flow in Turbomachines.* PREREQUISITE: AE 4431.

AE 4439 TURBOPROPULSION SYSTEMS (4-0). Application of fluid dynamics, thermodynamics and stress analysis to the design of turbomachinery for power plants for aircraft and vehicle propulsion. TEXT: Vavra, *Aerothermodynamics and Flow in Turbomachines.* PREREQUISITE. AE 4432.

AE 4451 AIRCRAFT AND MISSILE PROPULSION I (3-2). Description of various propulsion methods: rockets, ramjets, gas turbines, and, briefly, space propulsion. Includes parameters that specify system performance, information on current state of art and impact of trends in propulsion technology. Thrust and drag. Discussion of components: inlets, combustors, nozzles. Creative thinking is encouraged by discussion of novel propulsion schemes, stressing relationship to gas dynamics, mechanics and aerothermodynamics. TEXT: Instructor's Notes.

AE 4452 AIRCRAFT AND MISSILE PROPULSION II (3-2). Using the knowledge gained in AE 4451, the components are assembled, conceptually to form ramjets, turbofans, etc., for which performance (SFC, thrust) is predicted. Several missions (e.g., fighter aircraft, air-to-air missile) are defined and the best propulsion system is selected for each application. TEXT: Instructor's Notes. PREREQUISITE: AE 4451.

AE 4501 ADVANCED GASDYNAMICS (4-0). Similarity and perturbation methods applied to two-dimensional subsonic, supersonic and transonic flow. Shock wave interactions and reflections with reference to the hodograph plane. Method of characteristics: unsteady, and supersonic. Influence of viscosity and heat conduction on gas dynamics. TEXT: Owczarek, *Fundamentals of Gas Dynamics.*

AE 4502 HYPERSONIC FLOW AND REAL GAS EFFECTS (3-2). Hypersonic floflw with emphasis on small perturbation analysis, similarity solutions and Newtonian flow. Real gas effects will be studied (dissociation, ionization) with reference to problems such as Couette flow, the wavy wall, Prandtl-Meyer flow, and the plasma sheath. TEXT: Cox & Crabtree, *Elements of Hypersonic Aerodynamics.* PREREQUISITE: AE 4501.

AE 4503 AERODYNAMICS OF WINGS AND BODIES (3-2). Study of three-dimensional wings and bodies in subsonic and supersonic flow. Slender body theory and flow reversal theorems. Singular perturbation problems and unsteady flow. TEXT: Ashley and Landahl, *Aerodynamics of Wings and Bodies.* PREREQUISITE: AE 4501.

AE 4504 MAGNETO/ELECTROFLUIDDYNAMICS (3-2). Advanced energy conversion and propulsion systems which employ magneto/electrofluiddynamic principles. Definition and review of the pertinent physical concepts. Current and future applications. TEXT: Sutton and Sherman, *Engineering Magnetohydrodynamics.*

AE 4509 SPECIAL TOPICS IN GASDYNAMICS (4-0). Topics selected to illustrate typical research developments such as advances in the theory of fluid turbulence, computer simulation of fluid flow, advanced magnetohydrodynamics and/or electrohydrodynamics, high temperature effects in gas dynamics, the dynamics of rarified gases, hydrodynamic stability and transition, boundary layers in oscillating flows. May be repeated for credit when topic changes. PREREQUISITE: Consent of Department Chairman.

AE 4511 BOUNDARY LAYER THEORY (4-0). Some exact solutions of the Navier-Stokes equations. Boundary layer concept and equations, momentum and energy integrals, stability and transition. Fundamentals of turbulent flow; laminar and turbulent boundary layers with arbitrary pressure gradients. Techniques of solution. TEXT: Schlichting, *Boundary Layer Theory.*

AE 4512 CONVECTIVE HEAT AND MASS TRANSFER (4-0). Convective heat and mass transfer in ducts and from exposed surfaces; laminar and turbulent flows. Analytic techniques, integral and numerical methods, experimental correlations. Effects of variations in thermophysical properties. Combined heat and mass transfer. TEXTS: Kays, *Convective Heat Transfer.* PREREQUISITE: AE 4511.

AE 4519 SPECIAL TOPICS IN HEAT AND MASS TRANSFER (4-0). Selected topics in steady and non-steady heat transfer by radiation and conduction, multi-dimensional conduction, gas body radiation and hypersonic reentry heat and mass transfer. Offered to suit the needs of individual classes. May be repeated for credit when topic changes. PREREQUISITE: Consent of Department Chairman.

AE 4632 COMPUTER METHODS IN AERONAUTICS (3-2). Solution of eignevalue problems. Solution of ordinary and partial differential equations for aero-structures, gas dynamics, flight mechanics, dynamics and heat transfer. Introduction to computer graphics, design optimization, hybrid computers, and aerospace vehicle simulation. TEXT: Crandall, *Engineering Analysis.* PREREQUISITE: MA 3232.

AE 4831 TURBOMACHINERY LABORATORY I (0-3). Measurements of overall performance of turbomachines. PRE-

REQUISITE: AE 4431 concurrently.

AE 4832 TURBOMACHINERY LABORATORY II (0-3). Detailed investigations of stationary and rotating components of turbomachines. PREREQUISITE: AE 4432 concurrently.

AE 4900 ADVANCED STUDY IN AERONAUTICS (2-0 to 5-0). Directed graduate study or laboratory research. Course may be repeated for additional credit if topic changes. PREREQUISITE: Consent of Chairman.

AVIATION SAFETY PROGRAMS

JAMES CHRISTIAN NIELSEN, Associate Professor of Aeronautical Engr. and Safety; Director (1966)*; B.S.A.E., Univ. of Washington, 1950; M.S.A.E., 1957.

RUSSELL BRANSON BOMBERGER, Associate Professor of Law and Psychology (1958); B.S., Temple Univ., 1955; Ll.B., LaSalle Univ., 1968; J.D., 1969; M.A., Univ. of Lowa, 1956; M.S., Univ. of Scuthern California, 1960; M.A., Univ. of Iowa, 1961; Ph.D., 1962.

CRAIG MERRILL BRADBURY, Lieutenant Commander, U. S. Navy, Instructor in Aircraft Accident Prevention and Crash Investigation (1969); B.S., Naval Postgraduate School, 1963.

JOHN JOSEPH BRANSON, JR., Commander, U. S. Navy, Instructor in Aeronautical Engr. and Safety (1971); B.S., Naval Academy, 1950; B.S.A.E., Naval Postgraduate School, 1957; M.S., 1958.

LESTER CHARLES WIBLE, Assistant Professor of Aviation Accident Prevention and Crash Investigation 1965); B.S., Naval Academy, 1945.

** The year of joining the Postgraduate School Faculty is indicated in parentheses.*

The Aviation Safety Officers' Course is offered on a temporary additional duty basis to those Officers so ordered by the Chief of Naval Personnel. The following courses constitute the program and are taken simultaneously: AO 2310, AO 2320, AO 2352, AO 2360, and AO 2381.

Officers regularly enrolled in other curricula at the Postgraduate School may qualify as Aviation Safety Officers by completion of the program requirements.

AVIATION

Upper Division Courses

AO 2301 AERONAUTICAL ENGINEERING FOR AVIATORS (4-2). A survey of aeronautical engineering for the aviator and the Aviation Safety Officer. Basic aerodynamics, subsonic and supersonic aircraft characteristics, aircraft performance, stability and control, and aircraft structural limitations. PREREQUISITES: Mathematics through college algebra and geometry; physics through mechanics and heat. (This course is for students in the BA program.)

AO 2302 AVIATION ACCIDENT PREVENTION AND CRASH INVESTIGATION (3-2). This course consists of (a) a study of existing Navy Department instructions covering all aspects of accident investigation, prevention, and reporting procedures; (b) methods and techniques of accident investigation; (c) implementation and use of a prevention program; and (d) physiological factors of flight. PREREQUISITE: AO 2301 or AO 2303 (may be taken concurrently).

AO 2303 AERONAUTICAL ENGINEERING FOR AVIATORS (4-2). A survey of aeronautical engineering for the aviator and the Aviation Safety Officer. Basic aerodynamics, subsonic and supersonic aircraft characteristics, aircraft performance, stability and control, and aircraft structural limitations. PREREQUISITES: Mathematics through calculus, courses in thermodynamics, statics and dynamics. (This course is for students of the BS program.)

AO 2310 AERO ENGINEERING SAFETY (6-0). A survey of aeronautical engineering for the Aviation Safety Officer. Mathematics review, basic aerodynamics, subsonic and supersonic aircraft characteristics, aircraft performance, stability and control, and aircraft structural limitations.

AO 2320 AVIATION ACCIDENT PREVENTION AND CRASH INVESTIGATION (4-0). This course consists of (a) a study of existing Navy Department instructions covering all aspects of accident investigation, prevention, and reporting procedures; (b) methods and techniques of accident investigation; and (c) implementation and use of a prevention program.

AO 2360 AVIATION PHYSIOLOGY (2-0). A review of basic fundamentals of physiology with emphasis on the circulatory respiratory systems, vision and hearing, with the objective of understanding the principles associated with the physiological stresses encountered in aviation. The role of the squadron flight surgeon in the squadron training program and his duties in aviation accident prevention, investigation and reporting.

PSYCHOLOGY

Upper Division Course

AO 2352 PSYCHOLOGY IN ACCIDENT PREVENTION AND INVESTIGATION (4-0). A study of logical and psychological principles and practices useful in developing mental efficiency and emotional strength, designed especially for the Aviation Safety Officer.

LAW

Upper Division Course

AO 2381 AVIATION LAW (1-0). A study of the privileged status of the Aircraft Accident Investigation designed especially for the Aviation Safety Officer Program.

COMPUTER SCIENCE

Students interested in attaining either a baccalaureate or master's degree in Computer Science should consult with the Academic Associate for Computer Science, Professor Uno R. Kodres.

DEGREE REQUIREMENTS

BACHELOR OF SCIENCE WITH MAJOR IN COMPUTER SCIENCE

The requirements for a Bachelor of Science degree with major in Computer Science will include at least 10 hours in upper division mathematics, 6 hours in probability and statistics, 18 hours in computer science, and 4 hours in management.

MASTER OF SCIENCE IN COMPUTER SCIENCE

1. To obtain the Master of Science degree in Computer Science, the students must have satisfied the requirements for the Bachelor of Science degree in Computer Science.

2. In addition, the student must successfully complete a minimum of 40 quarter hours of graduate credit including:

	Minimum Hours
Computer Science	20
Mathematics	6
Operations Analysis or Electrical Engineering	6

3. In addition, the student must successfully complete an acceptable thesis.

COMPUTER SCIENCE

CS 0001 SEMINAR (0-1). Special lectures; guest lectures; discussion of student thesis research, faculty research projects. PREREQUISITE: None.

CS 0110 FORTRAN PROGRAMMING (3-0). The basic elements of FORTRAN are covered. Practical application of the principles is afforded by means of a series of problems of increasing difficulty.

CS 0810 THESIS RESEARCH (0-0). Every student conducting thesis research will enroll in this course.

Upper Division Courses

CS 2100 INTRODUCTION TO COMPUTERS AND FORTRAN PROGRAMMING (4-0). Characteristics of general purpose digital computers. Algorithmic approach to problem solving, considering numerical and non-numerical examples. Basics of machine language programming. Fundamentals of FORTRAN programming. Functions of compilers and assemblers. PREREQUISITE: None.

CS 2103 INTRODUCTION TO COMPUTERS AND COBOL PROGRAMMING (4-0). History of computers. Characteristics of digital computers and peripheral devices. Basics of machine language programming. Problem analysis and programming in COBOL. Problems selected from the area of business data processing. PREREQUISITE: None.

CS 2105 SURVEY OF COMPUTERS AND PROGRAMMING (4-0). A general appreciation of computer history, computer system organization, computer applications and computer management. Flowcharting and coding in the language BASIC. Not recommended for anyone intending to take further courses in computer science. PREREQUISITE: None.

CS 2110 INTRODUCTION TO COMPUTERS AND PROGRAMMING FOR COMPUTER SCIENCE MAJORS (3-2). Characteristics of general purpose digital computers. Algorithmic approach to problem solving, considering numerical and non-numerical examples. Basics of machine language and assembly language programming, emphasizing interactions with peripheral devices. FORTRAN programming. Characteristics of compilers, assemblers, and interpreters. Intended to provide more intensive coverage than CS 2100. PREREQUISITE: CS 0110 or the equivalent.

Upper Division or Graduate Courses

CS 3111 FUNDAMENTAL CONCEPTS IN STRUCTURAL PROGRAMMING LANGUAGES (4-0). An introduction to the significant features of programming languages. Formal definition of a language including specification of syntax and semantics. Characteristics of assemblers, compilers and interpreters. Properties of block structured languages, including scope of declarations, storage allocation and subroutines. Basic programming techniques, including string manipulation, list processing, bit manipulation and recursion. PREREQUISITE: Either CS 2100, CS 2103, CS 2110 or consent of the Instructor.

CS 3112 OPERATING SYSTEMS (4-0). Classical serial processing techniques, processor and Input-Output overlap. Multiprogramming, multiprocessing, stack-oriented processing. Addressing, indexing operations, storage allocation techniques. Time sharing, paging and task scheduling. Comparison of currently available large scale digital computer systems. PREREQUISITE: CS 2110 or CS 3111.

CS3200 STRUCTURE OF DIGITAL COMPUTERS (4-0). Boolean algebra, combinational and sequential circuits, arithmetic units, memory units, input-output devices, computer organization and control, microprogramming. PREREQUISITES: CS 2110 or equivalent.

CS 3201 COMPUTER SYSTEMS (4-0). System design concepts in computer hardware-software combinations. Processes, processors and virtual memory. Dynamic relocation using base registers, paging and segmentation. System communications — memory, auxiliary storage and input/output. Memory, control and capability protection. Resource allocation mechanisms, policies and problems. File system organization. Analysis, simulation and measurement techniques and their application to computer system design. Concepts are presented in terms of the fundamental insight provided by considering timesharing systems. PREREQUISITES: CS 3200, CS 3112.

CS 3204 DATA COMMUNICATIONS (4-0). Quantitative study of communication processes with emphasis on digital communication. Concepts fundamental to the engineering of accurate, efficient communication links and systems. Elements of information theory. Communication channels and their capacity, encoding and decoding of data over noisy channels. Error detection and correction coding schemes and procedures. Techniques and devices for effective data transmission in computer-based systems. PREREQUISITES: CS 3200 or EE 2810, PS 3401.

CS 3300 INFORMATION STRUCTURES (3-0). Basic concepts of data. Linear lists, strings, arrays, and orthogonal lists. Representation of trees and graphs. Storage systems and structures, and storage allocation and collection. Symbol tables and searching techniques. Sorting (ordering) techniques. Formal specification of data structures, data structures in programming languages, and generalized data management. PREREQUISITE: CS 3111.

CS 3601 AUTOMATA AND FORMAL LANGUAGES (3-0). Logical networks, neural networks, finite automata, minimalization of automata, regular expressions, context-free languages and push-down automata, context-sensitive languages and linear-bounded automata. Ambiguity in formal languages. PREREQUISITE: MA 2025 or equivalent.

CS 3800 DIRECTED STUDY IN COMPUTER SCIENCES (0-2 to 0-8). Individual research and study by the student under the supervision of a member of the faculty. Intended primarily to permit interested students to pursue in depth subjects not fully covered in formal class work. PREREQUISITE: Consent of the Instructor.

Graduate Courses

CS 4113 COMPILER DESIGN AND IMPLEMENTATION (3-2). Review of programming language structures, translation, loading, execution and storage allocation. Compilation of simple expressions and statements. Organization of a compiler: compile-time and run-time symbol tables; lexical and syntax scanning; object code generation; diagnostic procedures; object code optimization; and general design techniques. Use of translator writing systems. Laboratory will emphasize practical application of compiler implementation techniques. PREREQUISITES: CS 2110 and CS 3111.

CS 4202 INTERACTIVE COMPUTATION SYSTEMS (3-2). A study of the man-computer interface and methods for computer-assisted problem solving. System facilities for man-computer interaction. Computer graphics, transformations and graphics software. Data structures, memory requirements, storage, file and data management. Languages for man-computer interaction including graphics, command, problem-oriented, and special purpose languages. Laboratory work includes individual projects using interactive graphical consoles. PREREQUISITES: CS 3200, CS 3112, CS 3300 pre or corequisite, or consent of Instructor.

CS 4310 NON-NUMERICAL INFORMATION PROCESSING (4-0). Definition of heuristic versus algorithmic methods, rationale of heuristic approach, description of cognitive processes and approaches to mathematical invention. Objective of work in artificial intelligence, simulation of cognitive behavior and self-organizing systems. Heuristic programming techniques including the use of list-processing languages. Survey of examples from representative application areas. The mind-brain problem and the nature of intelligence. Class and individual projects to illustrate basic concepts. PREREQUISITE: CS 2110 or CS 3111.

CS 4900 ADVANCED TOPICS IN COMPUTER SCIENCE (3-0). Discussion of selected topics in the fields of current research in computer science. PREREQUISITE: Consent of Instructor.

Superb recreational facilities provide students with relaxation from study demands at the Naval Postgraduate School. Looking North from the main administration building, there is a putting green in the foreground, and beyond, an olympic swimming pool, "kiddie" pool and sauna bath. Tennis and handball courts are nestled among the trees. The Navy also operates an 18-hole golf course a mile from the campus.

DEPARTMENT OF ELECTRICAL ENGINEERING

SYDNEY RICHARD PARKER, Professor of Electrical Engineering; Chairman (1966)*; B.E.E., City College of New York, 1944; M.S., Stevens Institute of Technology, 1948; Sc.D., 1964.

RICHARD WILLIAM ADLER, Assistant Professor of Electrical Engineering (1969); B.S., Pennsylvania State Univ., 1956; M.S., 1958; Ph.D., 1970.

RALPH EDWARD BACH, JR., Associate Professor of Electrical Engineering (1971); B.S.E.E., Lehigh Univ., 1953; M.S.E.E., Northeastern Univ., 1958; Ph.D., 1964.

ORESTES METHODIUS BAYCURA, Associate Professor of Electrical Engineering (1966); B.S.E.E., Carnegie Institute, 1957; M.S., Univ. of Pittsburgh, 1959; D.Sc., 1963.

JOHN MILLER BOULDRY, Associate Professor of Electrical Engineering (1946); B.S., Northeastern Univ., 1941; M.S., Brown Univ., 1956.

STEPHEN BREIDA, Associate Professor of Electronics (1958); B.S.E.E., Drexel Institute of Technology, 1952; M.S.E.E., Purdue Univ., 1954.

SHU-GAR CHAN, Associate Professor of Electrical Engineering (1964); B.S., Univ. of Washington, 1954; M.S., Columbia Univ., 1954, Ph.D., Kansas Univ., 1964.

PAUL EUGENE COOPER, Professor of Electronics (1946); B.S., Univ. of Texas, 1937; M.S., 1939.

MITCHELL LAVETTE COTTON, Associate Professor of Electronics (1953); B.S., California Institute of Technology, 1948; M.S., Washington Univ., 1952; E.E., Univ. of California at Berkeley, 1954.

GERALD DEAN EWING, Associate Professor of Electrical Engineering (1963); B.S.E.E., Univ. of California at Berkeley, 1957; M.S.E.E., 1959; E.E., Oregon State Univ., 1962; Ph.D., 1964.

JOHN MICHAEL GEIST, Lieutenant, U. S. Naval Reserve; Assistant Professor of Electrical Engineering (1970); B.S.E.E., Univ. of Notre Dame, 1966; M.S.E.E., 1968; Ph.D., 1970.

ALEX GERBA, JR., Associate Professor of Electrical Engineering (1959); B.E.E., Univ. of Louisville, 1947; M.S., Univ. of Illinois, 1957.

DAVID BOYSEN HOISINGTON, Professor of Electronics (1947); B.S., Massachusetts Institute of Technology, 1940; M.S., Univ. of Pennsylvania, 1941.

RAYMOND KENNETH HOUSTON, Professor of Electrical Engineering (1946); B.S., Worcester Polytechnic Institute, 1938; M.S., 1939.

STEPHEN JAUREGUI, JR., Associate Professor of Electrical Engineering (1971); B.S., Univ. of California at Berkeley, 1954; M.S., Naval Postgraduate School, 1960; Ph.D., 1962.

DONALD EVAN KIRK, Associate Professor of Electrical Engineering (1965); B.S., Worchester Polytechnic Institute, 1959; M.S., Naval Postgraduate School, 1961; Ph.D., University of Illinois, 1964.

CLARENCE FREDERICK KLAMM, JR., Professor of Electronics (1951); B.S., Washington Univ., 1943; M.S., 1948.

JEFFREY BRUCE KNORR, Assistant Professor of Electrical Engineering (1970); B.S., Pennsylvania State Univ., 1963; M.S., 1964; Ph.D., Cornell Univ., 1970.

GEORGE HEINEMANN MARMONT, Professor of Electronics (1959); B.S., California Institute of Technology, 1934; Ph.D., 1940.

CARL ERNEST MENNEKEN, Professor of Electronics (1942); B.S., Univ. of Florida, 1932; M.S., Univ. of Michigan, 1936.

ROBERT LEE MILLER, Professor of Electronics (1946); B.Ed., Illinois State Normal Univ., 1936; M.S. Univ. of Illinois, 1941.

RAYMOND PATRICK MURRAY, Asssociate Professor of Electronics (1947); B.S., Kansas State College, 1937; M.S., Brown Univ., 1953.

GLEN ALLEN MYERS, Associate Professor of Electrical Engineering (1965); B.S.E.E., Univ. of North Daktota, 1955; M.S.E.E. Stanford Univ., 1956; Ph.D., 1965.

HERBERT LEROY MYERS, Assistant Professor of Electrical Engineering (1951); B.S., Univ. of Southern California, 1951.

JOHN EVERETT OHLSON, Associate Professor of Electrical Engineering (1971); B.S., Massachusetts Institute of Technology, 1962; M.S.E.E., Stanford Univ., 1963, Ph.D., 1967.

RUDOLF PANHOLZER, Associate Professor of Electrical Engineering (1964); Dipl. Ing., Technische Hochschule in Graz, Austria, 1953; D.Sc., 1961; M.S.E.E., Stanford Univ., 1956.

JOHN PATRICK POWERS, Assistant Professor of Electrical Engineering (1970); B.S.E.E., Tufts Univ., 1965; M.S., Stanford Univ., 1966; Ph.D., Univ. of California at Santa Barbara, 1970.

VICTOR MICHAEL POWERS, Assistant Professor of Electrical Engineering (1970); B.S.E.E., Univ. of Michigan, 1963; M.S., 1964; Ph.D., 1970.

THOMAS GORDON PRICE, JR., Ensign, U. S. Naval Reserve; Instructor in Electrical Engineering (1971); B.S.E.E., Univ. of Texas, 1968; M.S., Stanford Univ., 1970.

GEORGE ANTHONY RAHE, Associate Professor of Electrical Engineering (1965); B.S., Univ. of California at Los Angeles, 1957; M.S., 1959; Ph.D., 1965.

CHARLES HARRY ROTHAUGE, Professor of Electrical Engineering (1949); B.E., John Hopkins Univ., 1940; D.Eng., 1949.

GEORGE LAWRENCE SACKMAN, Associate Professor of Electrical Engineering (1964); B.M.E., Univ. of Florida, 1954; B.E.E., 1957; M.S.E., 1959; Ph.D., Stanford Univ., 1964.

ABRAHAM SHEINGOLD, Professor of Electronics (1946); B.S., College of the City of New York, 1936; M.S., 1937.

WILLIAM CONLEY SMITH, Professor of Electrical Engineering (1946); B.S., Ohio Univ., 1935, M.S., 1939.

DONALD ALAN STENTZ, Associate Professor of Electronics (1949); B.S., Duke Univ., 1949; M.S., Naval Postgraduate School, 1958.

ROBERT DENNY STRUM, Associate Professor of Electrical Engineering (1958); B.S., Rose Polytechnic Institute, 1946; M.S., Univ. of Santa Clara, 1964.

TIEN-FAN TAO, Associate Professor of Electrical Engineering (1971); B.S., National Taiwan Univ., 1955; M.S., Univ. of Pennsylvania, 1958; Ph.D., Harvard Univ., 1963.

FREDERICK WALCUTT TERMAN, Assistant Professor of Electrical Engineering (1964); B.S., Stanford Univ., 1949; M.S., 1950.

GEORGE JULIUS THALER, Professor of Electrical Engineering (1951); B.E., Johns Hopkins Univ., 1940; D. Eng., 1947.

HAROLD ARTHUR TITUS, Professor of Electronics (1962); B.S., Kansas Univ., 1952; M.S. Stanford Univ., 1957; Ph.D., 1962.

JOHN BENJAMIN TURNER, JR., Associate Professor of Electronics (1955); B.S., Univ. of Arkansas, 1941; M.S., Univ. of California at Berkeley, 1948.

CHENG-CHI PETER WANG, Assistant Professor of Electrical Engineering, (1971); B.S., National Taiwan Univ., 1963; M.S., Oregon State Univ., 1966; Ph.D., Univ. of California at Los Angeles, 1971.

JOHN ROBERT WARD, Professor of Electrical Engineering (1962); B.Sc., Univ. of Sydney, 1949; B.E., 1952; Ph.D., 1958.

MILTON LUDELL WILCOX, Associate Professor of Electrical Engineering (1958); B.S., Michigan State Univ., 1938; M.S., Univ. of Notre Dame, 1956.

EMERITUS FACULTY

WILLIAM MALCOM BAUER, Professor Emeritus (1946); B.S., Northwestern Univ., 1927; E.E., 1928; M.S., Harvard Univ., 1929; D.Sc., 1940.

JESSE GERALD CHANEY, Professor Emeritus (1944); A.B., Southwestern Univ., 1924; A.M., Univ. of Texas, 1930.

EDWARD MARKHAM GARDNER, Professor Emeritus (1948); B.S., Univ. of London, 1923; M.S., California Institute of Technology, 1938.

GEORGE ROBERT GIET, Dintinguished Professor Emeritus (1925); A.B., Columbia Univ., 1921; E.E., 1923.

CHARLES BENJAMIN OLER, Professor Emeritus (1946); B.S., Univ. of Pennsylvania, 1927; M.S., 1930; D. Eng., Johns Hopkins Univ., 1950.

ORVAL HAROLD POLK, Professor Emeritus (1945); B.S., Univ. of Colorado, 1927; M.S., Univ. of Arizona, 1933; E.E., Univ. of Colorado, 1940.

ALLEN EDGAR VIVELL, Dean Emeritus (1945); B.E., Johns Hopkins Univ., 1927; D. Eng., 1937.

RICHARD CARVEL HENSEN WHEELER, Professor Emeritus (1929); B.E., Johns Hopkins Univ., 1923; D. Eng., Rensselear Polytechnic Institute, 1926.

** The year of joining the Postgraduate School Faculty is indicated in parentheses.*

DEPARTMENTAL REQUIREMENTS FOR DEGREES IN ELECTRICAL ENGINEERING

In addition to meeting the minimum specific academic requirement for these degrees as given below, candidates must also satisfy the general degree requirements as determined by the Academic Council.

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

1. Candidates for this degree must generally satisfy the following requirements while in residence at the Naval Postgraduate School, except in the case of candidates entering the school with advanced standing, when due allowance will be made for advanced transfer credits.

Discipline:	*Subject:*	*Approximate Quarter Hours:*
Electrical Engineering	Fields and Circuits	13
	Electronic Devices and Circuits	15
	Communication Theory	4
	Electromagnetic Theory	3
	Energy Conversion	4
	Electronic Computers	4*
	Control Theory	4
		47
Mathematics	Calculus, vectors, matrices, series, differential equations and complex variables	12

* Courses in computer programming or theory with MA and CS prefixes may be substituted for electrical engineering courses in computers with approval of the Chairman of the Department.

2. An additional 11 quarter hours are to be taken in upper division courses in Electrical Engineering and 9 quarter hours in areas such as mechanics, dynamics, properties of matter, physical chemistry and thermodynamics. Minor departures from these requirements may be approved by the Department as long as the total number of hours in upper division courses is not reduced.

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

A minimum of 40 quarter hours of graduate work beyond the requirements for the Bachelor of Science in Electrical Engineering degree shall be required for the degree of Master of Science in Electrical Engineering. The academic records of those students who do not complete the requirements for the Bachelor of Science in Electrical Engineering degree at the Naval Postgraduate School will be evaluated by the Department of Electrical Engineering to determine what additional undergraduate courses need be taken

to qualify for entry into the graduate program. Of the 40 quarter hours a minimum of four courses, of at least 12 hours, must be in the course sequence 4000-4999. At least 30 hours shall be required in Electrical Engineering subject. An acceptable thesis must be presented. An acceptable thesis for the Engineer's Degree may also be accepted as meeting the thesis requirements of the Master's Degree.

ELECTRICAL ENGINEER

1. Students with acceptable academic backgrounds may enter a program leading to the degree Electrical Engineer. Normally, this program is of three years' duration. Candidates for the Engineer's degree are selected during their second year in residence.

2. A minimum of 80 graduate course credits are required for the award of the Engineer's degree. Of these at least 30 hours are to be in the courses in the sequence 4000-4999. An acceptable thesis must be completed. A departmental advisor will be appointed for consultation in the development of a program of study. Approval of all programs must be obtained from the Chairman, Department of Electrical Engineering.

DOCTOR OF PHILOSOPHY

The Department of Electrical Engineering has an active program leading to the degree of Doctor of Philosophy. Areas of special strength in the departgrams with the Department of Physics are possible. cesses and devices, and control theory. Joint programs with the Department of Physics are possible. The degree requirements are as outlined under the general school requirements for the Doctor's degree.

ELECTRICAL ENGINEERING LABORATORIES

The Electrical Engineering Department Laboratories have excellent facilities in almost all phases of modern electrical engineering, and are continuously under careful development. At present the laboratories are divided into energy conversion, solid state, lasers, control systems, radar and electronic countermeasures, sonar, communication and navigation, microwaves and antennas, computers, and general measurement laboratories. In addition, there are extensive service facilities including a calibration laboratory where a continuous program of calibration and maintenance of laboratory instruments is carried out.

In addition to the usual experimental and instructional type laboratories, status as a Naval facility enables the Department to utilize a number of modern systems as adjuncts to the laboratory. These include communications, radar, telemetry, sonar, countermeasures and navigational systems.

The Computer laboratory of the Department of Electrical Engineering is a school-wide direct access computer complex wherein each student may program and operate the computer system for the solution of his own problem. The facility includes a medium size digital computer, two high performance input-output display units, and a general purpose hybrid/analog computer; all integrated into a single system. These facilities support a wide range of research and instruction in digital and hybrid computation and simulation.

As a part of the laboratory facility, there are generous research spaces available for thesis students to conduct their research problems on an individual basis.

BIOENGINEERING/BIOMEDICAL STUDIES

The Department of Electrical Engineering has responsibility for the biology courses listed below. These courses, together with certain ones offered by other departments (e.g., PH 4855, PH 4999, OA 3657, OA 3658, OA 4680), can be included, as appropriate, in the curriculum of a student interested in a bioengineering/biomedical program as part of his studies toward a degree.

Upper Division or Graduate Courses

EE 3800 CELLULAR AND MOLECULAR BIOLOGY (4-0). The fundamental principles of the living cell covered from a biochemcal and biophysical standpoint. The structure and role of macro-molecules in the cell is studied; in particular DNA, RNA and their relations to cell function, to the synthesis of proteins, and to genetics. PREREQUISITES: CH 3401, and a course in probability and statistics.

EE 3801 HUMAN PHYSIOLOGY (5-0). A comprehensive course in mammalian physiology, emphasizing human functional aspects. PREREQUISITE: EE 3800.

EE 3820 BIOELECTRONIC INSTRUMENTATION (3-3). The application of electronic methods to biological and medical measurements is treated in depth. The special problems involved, such as design of electrodes and input amplifiers, and the conversion of data to meaningful parameters are studied. The laboratory includes actual measurement procedures, using living material. PREREQUISITES: EE 3801, EE 2103, EE 2212.

Graduate Courses

EE 4802 RADIATION BIOLOGY (5-0). Fundamental processes of energy transfer from radiation to living matter. Biochemical, physiological and genetic effects of radiation. Methods of experimental radiation biology. PREREQUISITES: EE 3801 and appropriate courses in nuclear physics.

EE 4822 SPECIAL TOPICS IN RADIATION BIOLOGY (2-0). Study of important current topics in radiation biology. PREREQUISITE: Appropriate biological background.

EE 4840 NEURAL SIGNAL PROCESSING AND CONTROL (3-3). This course extends the coverage of neurophysiology beyond that given in EE 3801 Human Physiology. Lecture material describes the basic structure and performance of neural circuits especially those involved in sensory processing (visual, aural, etc.), those involved in multi-synaptic reflex arcs, including inhibitory action, and those involved in muscular control. Associative and integrative functions of the fore brain are studied. The laboratory part consists of experiments using living material and projects where basic models of neural processes would be set up and their performance measured, using real time computer processing as appropriate. PREREQUISITES: EE 3801, EE 3820, EE 2103, EE 2212, CS 2100 or equivalent.

EE 4880 ADVANCED TOPICS IN HUMAN PHYSIOLOGY (4-0). Recent advances in the study of human physiological systems are presented. The areas covered include circulation and heart, renal function, metabolic interrelations, endocrine systems and their control, immunology, and recent research in neurophysiology and the special senses. PREREQUISITES: EE 3801, EE 4840.

EE 4890 COMPUTER MODELING OF BIOLOGICAL SYSTEMS (2-4). This is a seminar and project type course. Its exact content will vary with the interests of the instructors and students. However, examples of models of biological systems, as reported in the current literature, will be studied, and, as laboratory projects, one or more new models will be devised and analyzed, using computer techniques. PREREQUISITES: EE 3801, EE 4840, EE 4414 or equivalent. A stochastic modeling course such as OA 3704 is desirable.

COMPUTER SCIENCE

Computer Science is an interdepartmental effort involving the Departments of Electrical Engineering and Mathematics. Complete descriptions of the following courses may be found on page 73.

CS 0001 SEMINAR (0-1).

CS 0110 FORTRAN PROGRAMMING (3-0).

CS 0810 THESIS RESEARCH (0-0).

Upper Division Courses

CS 2100 INTRODUCTION TO COMPUTERS AND FORTRAN PROGRAMMING (4-0).

CS 2103 INTRODUCTION TO COMPUTERS AND COBOL PROGRAMMING (4-0).

CS 2105 SURVEY OF COMPUTERS AND PROGRAMMING (4-0).

CS 2110 INTRODUCTION TO COMPUTERS AND PROGRAMMING FOR COMPUTER SCIENCE MAJORS (3-2).

Upper Division or Graduate Courses

CS 3111 FUNDAMENTAL CONCEPTS IN STRUCTURAL PROGRAMMING LANGUAGES (4-0).

CS 3112 OPERATING SYSTEMS (4-0).

CS 3200 STRUCTURE OF DIGITAL COMPUTERS (4-0).

CS 3201 COMPUTER SYSTEMS (4-0).

CS 3204 DATA COMMUNICATIONS (4-0).

CS 3300 INFORMATION STRUCTURES (3-0).

CS 3601 AUTOMATA AND FORMAL LANGUAGES (3-0).

CS 3800 DIRECTED STUDY IN COMPUTER SCIENCES (0-2 to 0-8).

Graduate Courses

CS 4113 COMPILER DESIGN AND IMPLEMENTATION (3-2).

CS 4202 INTERACTIVE COMPUTATION SYSTEMS (3-2).

CS 4310 NON-NUMERICAL INFORMATION PROCESSING (4-0).

CS 4900 ADVANCED TOPICS IN COMPUTER SCIENCE (3-0).

The engineering aspects of computers are also covered in EE 2810, EE 3812, EE 3822, and EE 4823.

DEFENSE COMMUNICATIONS

Upper Division Courses

CO 2111 DEFENSE COMMUNICATIONS ORGANIZATION AND PLANNING (4-0). Organization and functions of Department of Defense Communications Systems, including command and control functions. A study of the National Communications System, Defense Communications Systems, and the complete Naval communications organization, including the Naval Security Group. Integration of the various organizational systems is emphasized. The role of communications in the Naval Planning process is studied as well as an introduction to communications planning.

CO 2112 DEFENSE COMMUNICATION SYSTEMS (3-2). Brief review of the development of the broadcast, ship-shore and tactical communication systems and sub-systems within the Navy, and their relationship to the Defense Communication System. Systems schemes and outlines of AUTODIN, AUTOVON, Multi-Channel, Tactical Satellite and ON-Line Cryptographic systems are studied with emphasis on problems and solutions associated with compatability, installation and operating procedures. PREREQUISITE: CO 2111.

ELECTRICAL ENGINEERING

EE 0110 REVIEW OF BASIC ELECTRICAL CONCEPTS (5-0). Topics include the current-voltage relations in simple circuits, circuit laws and theorems, elementary AC circuit concepts, physical definitions of circuit constants and laws of electron motion.

EE 0810 THESIS RESEARCH (0-0). Every student conducting thesis research will enroll in this course.

EE 0951 SEMINAR (0-1). Lectures on subjects of current interest will be presented by invited guests from other universities and from industry, as well as by faculty members of the Naval Postgraduate School.

Upper Division Courses

EE 2101 BASIC CIRCUIT THEORY (3-2). An introduction to electrical engineering circuit theory; the circuit concept and circuit elements; power and energy; Kirchoff's current and voltage laws; solutions of first-order and second-order circuits with various inputs and initial state conditions; time varying circuits and nonlinear circuits; state equations and trajectory. PREREQUISITE: Integral calculus and MA 2045 (may be concurrent).

EE 2102 CIRCUIT ANALYSIS (4-2). Solutions of network equations using basic Laplace transform; network functions, poles and zeros and natural frequencies; sinusoidal steady-state analysis; coupled circuits; network theorems and parameters. PREREQUISITES: EE 2101 or equivalent.

EE 2103 LINEAR SYSTEMS ANALYSIS (4-2). Fourier transform methods; convolution; state-variable formulation and solution; signal flow graphs; simulation of linear systems on analog and digital computers. PREREQUISITES: EE 2102; Differential Equations; Complex variable theory and FORTRAN may be concurrent.

EE 2111 ELECTRICAL FUNDAMENTALS FOR AERONAUTICAL ENGINEERS (4-2). An intensive course covering the fundamentals of Electrical Engineering including both circuits and electronic devices for students in Aeronautical Engineering. PREREQUISITES: MA 2047, MA 3130, MA 3173 or equivalent.

EE 2114 COMMUNICATION THEORY I (4-0). In this introductory course the following concepts and their mathematical formulations are presented: power spectral density; matched filters; sampling; pulse encoding methods; frequency and time multiplexing; amplitude, frequency and phase modulation. In addition, a comparison of modulation methods is presented. PREREQUISITES: EE 2103 and EE 2212.

EE 2201 ELECTRONICS SURVEY (4-2). A one-term survey course for non-electrical engineering curricula, with emphasis on the general operational characteristics of representative electronic devices. Topics included are: physical process in common devices; current-voltage relations of diodes and active devices; basic electronic circuits. PREREQUISITE: EE 2101.

EE 2211 ELECTRONIC ENGINEERING FUNDAMENTALS I (4-2). A general introduction to electronic devices and circuits; brief consideration of vacuum devices; the electrical properties and charge flow mechanisms of semiconductor materials; properties of p-n junctions with emphasis on their role in diodes and bipolar transistors; application of diodes in circuits, particularly in rectifiers; static bipolar transistor models; MOS and junction FET's. PREREQUISITE: EE 2102 (may be concurrent).

EE 2212 ELECTRONIC ENGINEERING FUNDAMENTALS II (4-3). Topics include analysis of linear amplifiers; determination of device parameters; design of biasing circuits; multi-state amplifiers; properties of common amplifier configurations; feedback amplifiers; tuned amplifiers; and power amplifiers. PREREQUISITE: EE 2211.

EE 2216 PULSE AND DIGITAL CIRCUITS (4-3). The topics studied include basic waveform characteristics and shaping techniques, wide-band linear amplifiers, characteristics of electronic switching devices, clipping, clamping and switching circuits, multivibrator and trigger circuits, time-base generators, logic circuits, counting and timing circuits. PREREQUISITE: EE 2212.

EE 2217 COMMUNICATION CIRCUITS (4-3). Electronic circuits used for the transmission and reception of analog and digital signals. Topics include oscillators, modulators and demodulators, frequency converters, and special-purpose amplifiers. PREREQUISITES: EE 2216, EE 2114.

EE 2222 ELECTRONIC FUNDAMENTALS I (3-2). The first of a sequence for nonengineering curricula. An introduction to electronic devices, circuits and systems is followed by a consideration of basic concepts of electrical circuit analysis, electronic conduction and emission processes in electronic devices and operational properties of diodes and control devices. PREREQUISITE: A course in calculus.

EE 2223 ELECTRONIC FUNDAMENTALS II (3-3). A continuation of EE 2222. Included topics are linear amplifier analysis, feedback techniques, tuned amplifiers, power amplifiers, and electronic power supplies. PREREQUISITE: EE 2222.

EE 2224 COMMUNICATION AND DIGITAL ELECTRONICS (4-3). Frequency spectra for information transmission, oscillators, modulation and demodulation techniques, frequency conversion, pulse circuits and digital techniques, communication transmitters and receivers. PREREQUISITE: EE 2223.

EE 2311 PRINCIPLES OF ENERGY CONVERSION (3-2). An introduction to the principles of energy conversion. Topics presented are thermoelectric, thermionic, photovoltaic, electrochemical and electromagnetic methods of energy conversion. PREREQUISITES: EE 2102, EE 2211, permission of Instructor.

EE 2411 CONTROL SYSTEMS (3-3). Introduction to the analysis and design of linear feedback control systems by means of s-plane and frequency response methods. Analysis using state variables; design using frequency and time domain performance indices is discussed. Laboratory work includes simulation using analog and digital computers; testing and evaluation of physical systems. PREREQUISITES: EE 2103 and MA 2232 or their equivalent.

EE 2421 INTRODUCTION TO COMMUNICATIONS TECHNOLOGY (4-2). The first of a sequence of five courses designed for the Communications Management Specialist. An introduction is given to the basic elements of the communication system, followed by pertinent principles of electrical circuits and fundamentals of electronic devices. PREREQUISITE: A course in calculus.

EE 2422 COMMUNICATIONS SYSTEMS I (4-3). A continuation of EE 2221. The topics covered are: The general analog communications system with identification of subsystems; power conversion, oscillators, modulation and demodulation, special purpose circuits, elementary communication theory. PREREQUISITE: EE 2421.

EE 2423 COMMUNICATIONS SYSTEMS II (4-3). A study of digital communication systems. The general concepts of digital signalling are covered, followed by a consideration of elementary switching and shaping circuits, logical processing and logic circuits, the digital computer as a communication sub-system, and elementary digital-data transmission theory. PREREQUISITE: EE 2422.

EE 2424 SIGNAL TRANSMISSION SYSTEMS (4-2). This course covers the elements of electrical energy transmission as applied to communications. The principles of electromagnetic waves are presented, guided waves on transmission lines and waveguides are studied. The radiated field in space, antennas and propagation are covered, and a representative system, such as a satellite communications system is studied. PREREQUISITE: EE 2423 (may be concurrent).

EE 2621 INTRODUCTION TO FIELDS AND WAVES (4-0). Static field theory is developed and applied to boundary value problems. Time-varying Maxwell equations are developed and solutions to the wave equations are presented. Additional topics include skin effect, reflection of waves and radiation. PREREQUISITE: EE 2103.

EE 2622 ELECTROMAGNETIC ENGINEERING (3-1). A continuation of EE 2621. Topics include transmission lines, waveguides and cavity resonators. Applications are presented in the laboratory. PREREQUISITES: EE 2621.

EE 2810 DIGITAL MACHINES (3-3). Basic principles of digital system design with emphasis upon the organization and programming of simple computers. Elements of Boolean algebra and logic design. Storage organization and control. Input-output data flow. Relation of machine logic to program design. Laboratory sessions are devoted to study of computer logical elements, processing, storage, and I/O units. PREREQUISITE: CS 2100.

Upper Division or Graduate Courses

EE 3111 AVIONIC SYSTEMS (4-2). A course designed to provide as much background as possible in avionic systems for aeronautical engineers. Topics included are: radar principles, avionic computers, laser and infrared devices, sonar, navigation systems, systems engineering. PREREQUISITE: EE 2111.

EE 3116 COMMUNICATION THEORY II (3-2). A continuation of EE 2114. The concept of information measure (entropy) is introduced and its significance for communication systems is discussed. Noise sources and their measurement are treated. Statistical methods for handling noise and random signals are presented, followed by a study of detection problems in radar and pulse transmission systems. Correlation functions and their applications to communication systems are introduced. PREREQUISITES: EE 2114; a course in probability and statistics.

EE 3215 MICROWAVE DEVICES (4-2). Electron tube and solid state microwave devices are studied. Klystrons, magnetrons, traveling wave tubes, microwave transistors, tunnel diodes, varactors, bulk effect, quantum electronic and other current devices are among those included. PREREQUISITES: EE 2212, EE 2622, PH 2641, or permission of Instructor.

EE 3263 INTEGRATED CIRCUITS (3-3). Fabrication of bipolar and MOS integrated circuits; principles and applications of IC building blocks such as differential amplifiers, operational amplifiers and other linear IC circuits; gates, flip-flops, shift registers, counters and other digital IC circuits; trends in IC developments. PREREQUISITE: EE 2216.

EE 3264 ADVANCED THEORY OF SEMICONDUCTOR DEVICES (4-0). Application of solid state theory to the analysis of modern semiconductor devices such as high frequency diodes and transistors, infrared and optical sensors, photodiodes and phototransistors, light-emitting diodes, p-n junction and heterojunction lasers, etc. PREREQUISITES: EE 2212 and PH 3741 or equivalent.

EE 3311 ENERGY CONVERSION (3-2). A consideration and application of principles used in the conversion of energy to the electric form. Devices utilizing these principles are analyzed and include thermoelectric, thermionic, electrochemical and others. A term paper based on library research in the energy conversion field is required. PREREQUISITES: EE 2102, EE 2211, permission of the Instructor.

EE 3312 ELECTROMAGNETIC MACHINES (3-4). The model oriented approach to the analysis of rotating machines and amplifiers is utilized to obtain their dynamic and steady state characteristics. DC motors, generators and control machines are analyzed. PREREQUISITES: EE 2311 or EE 3311, EE 2103.

EE 3313 MARINE ELECTRICAL ANALYSIS AND DESIGN (2-4). Design principles of electric machines are studied. Symmetrical components are presented and applications are made in the short circuit analysis of a portion of a ship's power distribution system. A computer study of a static excitation system is made. PREREQUISITES: EE 3312 and EE 2411.

EE 3314 DISTRIBUTION AND CONVERSION OF ELECTRICAL ENERGY. (3-2). An introduction to the steady state and dynamic operation of electric motors and generators. General transformer principles. A ships power distribution system and its protection is considered. Polyphase circuits and symmetrical components are introduced as needed. PREREQUISITE: EE 2102.

EE 3413 FUNDAMENTALS OF AUTOMATIC CONTROL (3-3). A course in the fundamentals of automatic control theory and practice, primarily for nonelectrical engineering curricula. Topics include analysis and design of linear feedback control systems using frequency and time-domain techniques. Performance indices are discussed with application to the broad field of controls. Laboratory work includes computer simulation and test and evaluation of physical systems. PREREQUISITES: MA 3132 and EE 2102, or permission of Instructor.

EE 3422 MODERN COMMUNICATIONS (3-2). A study of modern communications trends, with emphasis on theoretical study of current and proposed systems. The topics covered include multiplex systems, coding, and pseudo-random noise modulation systems. PREREQUISITE: EE 3116 or EE 4571.

EE 3425 COMMUNICATION SYSTEMS ANALYSIS (3-3). The final course in the Communications Management sequence. The objective is to look at the overall Communications System with particular attention to system aspects. Some of the subjects considered are: underlying communication theory, multiplexing methods, evaluation and selection of systems, modern trends in systems. PREREQUISITE: EE 2424.

EE 3432 RADAR SYSTEMS (3-2). The principles of pulse radar systems are developed in classroom and laboratory exercises. Additional topics developed include the radar equation, doppler systems, automatic target-tracking systems, pulse compression, and multiple-unit steerable-array radars. PREREQUISITES: EE 2114, EE 3215, and EE 2622.

EE 3471 GUIDANCE AND NAVIGATION (3-2). A study of the principles involved in the guidance and navigation of platforms operated in a water, air or space environment. Topics include: beam forming directional sensing techniques, interrogation methods; time and phase difference systems; high resolution methods including inertial, celestial, and optical techniques; and closed loop telemetry systems used for automatic guidance. PREREQUISITES: EE 2411, EE 3631.

EE 3622 ELECTROMAGNETIC THEORY (3-1). Electromagnetic theorems and concepts are introduced. Plane, cylindrical and spherical wave functions are applied to problems of wave propagation, radiation, scattering and diffraction. Periodic and traveling wave structures are analyzed. PREREQUISITE: EE 2622.

EE 3631 ANTENNAS AND PROPAGATION (3-2). An engineering course covering the major classes of antennas for communications and radar followed by a study of the properties of the atmosphere and its effect on the propagation of surface, space, and sky waves. While essentially stressing engineering, the course applies to practical systems the field theory presented in earlier courses. PREREQUISITES: EE 2622.

EE 3641 ELECTROMAGNETIC COMPATABILITY (3-1). An introduction to sources of electromagnetic interference and techniques for making electronic systems compatible. Receivers, transmitters and antennas are examined in communication, signal processing and radar systems. EMC tests and interference predictions are discussed. PREREQUISITES: EE 2217, EE 2622.

EE 3652 MICROWAVE CIRCUITS AND MEASUREMENTS (3-2). A continuation of EE 2622. Waveguides and cavities will be discussed in more detail and perturbation theory will be introduced. Other topics may include coupled lines, periodic circuits, strip line techniques, scattering parameters, and ferrites as well as topics from the current literature. Microwave measurement techniques will be presented in the laboratory. PREREQUISITE: EE 2622.

EE 3731 INSTRUMENTS AND EQUIPMENT FOR OCEAN OPERATION (4-3). A study of measuring techniques, sensors, transducers and special electrical and sonic equipment for data-gathering, processing and communications in a deep-water environment. Specific topics covered include nagivational instruments, precise positioning, high-pressure electrical circuitry, communications, acoustic transducers and systems, motors and underwater power supplies. PREREQUISITES: PH 3421 and an undergraduate course in electronics.

EE 3812 SWITCHING THEORY AND LOGIC DESIGN (3-2). Models for logic elements and networks. Equivalence and machine minimization. Threshold logic. Synthesis of combinational and sequential networks. State assignment. Applications to digital machine design. Laboratory work is oriented around a project in logic network design. PREREQUISITE: EE 2810.

EE 3822 ENGINEERING APPLICATIONS OF COMPUTERS (3-3). Use of digital, analog, and hybrid computing machines in various application areas, e.g., systems design, parameter optimization, adaptive control, data acquisition and filtering, signal processing, biomedical instrumentation. Special techniques for real-time processing and simulation. Laboratory work is conducted in small groups and involves applications studies using the various types of computers. PREREQUISITE: EE 2810.

EE 3831 COMPUTER-AIDED NETWORK ANALYSIS AND DESIGN (3-2). Introduction to the application of computers in the analysis and design of passive and active networks. Topics included are: linear and non-linear networks; DC, AC, and transient analysis; sensitivity and optimization problems; off-line and on-line designs; theory and application of various general

and special-purpose computer programs such as ECAP, CORNAP, CALAHAN, NASAP. Students will use these programs for their design problems. PREREQUISITES: EE 2211, EE 2103, and CS 2100, or equivalent.

Graduate Courses

EE 4121 ADVANCED NETWORK THEORY I (3-2). Topology. Circuit formulations, nonlinear modeling, and computer solution. Circuit sensitivity models. Concepts and tests for passivity, activity, causality, and stability. Driving point synthesis. Introduction to transfer function properties and synthesis. PREREQUISITES: EE 2103 and EE 2211.

EE 4122 ADVANCED NETWORK THEORY II (3-2). Transfer function synthesis. N-port properties. N-port synthesis. The scattering matrix. The approximation problem. PREREQUISITE: EE 4121.

EE 4123 ADVANCED NETWORK THEORY III (3-2). Topics selected from the following: Active network synthesis. Topological synthesis. Time-domain synthesis. Advanced computer methods in network design. PREREQUISITE: EE 4122.

EE 4410 MATHEMATICAL MODELS AND SIMULATION FOR CONTROL SYSTEMS (3-2). Modeling of linear and nonlinear systems. Modeling concepts and techniques. Philosophy of model studies. Verification of the model and its parameters. Design studies using computer models. PREREQUISITE: EE 2411.

EE 4412 NONLINEAR SYSTEMS (3-3). Techniques for the analysis of nonlinear feedback systems. Phase plane and describing function analysis. Relay servomechanisms. Lyapunov method. Popov stability. Laboratory work includes analog and digital simulation. PREREQUISITE: EE 2411.

EE 4414 STOCHASTIC CONTROL THEORY (2-2). Statistical and probabilistic concepts are applied to the development of optimal methods for estimation, prediction, and identification. These methods are applied to the stochastic control problem. PREREQUISITES: EE 2411 and PS 3411.

EE 4415 ALGEBRAIC METHODS IN CONTROL THEORY (3-0). This course treats advanced concepts in root-locus theory including graphical and analytical (algebraic) design of compensation. Extension is made to two-parameter analysis and design. The Mitrovic-Siljak relationships are developed, leading to the coefficient plane and parameter-plane methods. Stability analysis, adjustment, design and synthesis using parameter-plane methods are treated in detail. Extensions to multiparameter problems are discussed. PREREQUISITE: EE 2411.

EE 4416 TOPICS IN MODERN CONTROL THEORY (3-0). A course intended to acquaint the student with recent developments in control as found in the research publications of the profession. Topics are selected at the direction of the instructor and may include such subjects as Adaptive Systems, Digital and Hybrid Simulation, Finite State Automata, Learning Systems, Lyapunov Methods, Popov Stability, Sensitivity, etc. PREREQUISITE: Consent of the Instructor.

EE 4417 OPTIMAL CONTROL (4-0). The optimal control problem is treated using the calculus of variations. Pontryagin's maximum principle, and dynamic programming. Optimal pursuit-evasion strategies are considered. PREREQUISITE: EE 2411.

EE 4418 SHIP CONTROL SYSTEMS (3-2). Theory of motion of ships. Basic ship control systems; steering, control roll stabilization, boiler control, loops, speed and propulsion controls. Sea states and their effects. Performance objectives and performance specifications. Models. Simulation studies. PREREQUISITE: EE 2411.

EE 4421 ELECTRO-OPTIC SYSTEMS ENGINEERING (3-1). Analysis and design of electro-optic systems such as laser communication, optical information processing, lasar radar, infra-red systems, low-light-level television. Emphasis is on system characteristics as determined by electro-optic devices. PREREQUISITES: EE 2114, EE 2622, or PH 3280.

EE 4422 TOPICS IN ELECTRO-OPTICS SYSTEMS (3-1). A course intended to acquaint the student with current developments in electro-optics as described in the research publications of the subject. Topics are selected at the discretion of the instructor and may include such subjects as Holographic Interferometry, Bragg Diffraction Imaging, High-Energy Lasers, Infrared technology, etc. PREREQUISITES: EE 4421 or equivalent, and consent of instructor.

EE 4433 ADVANCED RADAR SYSTEMS (3-2). The radar range equation is developed in a form including signal integration, the effects of target cross-section, fluctuations, and propagation losses. Modern techniques discussed include pulse compression, frequency-modulated radar, MTI, pulse doppler systems, monopulse tracking systems, multiple-unit steerable array radars, and synthetic aperture systems. Laboratory sessions deal with basic pulse radar systems from which the advanced techniques have developed, with pulse compression, and with the measurement of radar cross section of targets. PREREQUISITES: EE 2622, EE 3215$, EE 4571 (may be concurrent) and SECRET Clearance.

EE 4451 SONAR SYSTEMS ENGINEERING (3-2). A study of the theory and engineering practices pertaining to passive and active sonar systems. This study emphasizes the research and development of underwater acoustic surveillance systems. The objective of the course is to determine how the engineering design is conditioned by the characteristics of the transmission medium as well as the operational requirements. PREREQUISITES: PH 4454, EE 4571, EE 2212, U.S. Citizenship and SECRET Clearance.

EE 4452 UNDERWATER ACOUSTIC SYSTEMS ENGINEERING (4-2). A study of the theory and engineering principles of underwater acoustics, communications, surveillance, and navigational systems. Emphasis is placed on the principles and problems common to all underwater acoustic systems, and the design trade-offs that are available to the engineer. The laboratory periods are used for making engineering tests on existing systems and designing, building, and testing a system or subsystem of the student's own design. PREREQUISITES: EE 4571, EE 2212.

EE 4461 ADVANCED SYSTEMS ENGINEERING (3-1). An introduction to the engineering of large scale systems. The primary aim of this course is to increase the student's awareness of the complex interactions of various disciplines and the main recurring problems in systems engineering. The class will be expected to participate in a group project involving a feasibility study of a proposed new system. PREREQUISITES: EE 4571 and EE 2411.

EE 4473 MISSILE GUIDANCE SYSTEMS (3-1). Principles of intertial sensors and autonavigator systems. Radar and Infrared trackers. Trajectory analysis. Steering logic. Proportional navigation. Pursuit-evasion strategy. Control of ballistic and aerodynamic vehicles. Navigation and guidance in space. Laboratory work is concerned with testing of components and evaluation by computer simulation of complete guidance system performance. PREREQUISITES: EE 4412, EE 4433 or equivalent, and SECRET Clearance.

EE 4481 ELECTRONIC WARFARE TECHNIQUES AND SYSTEMS (3-3). Active and passive countermeasure techniques

are considered, including signal representation, signal analysis, and signal interception. Important parameters of radar and communications systems are defined. Denial and deceptive jamming techniques are considered along with counter measure and counter counter-measure techniques. Signal intercept systems are treated. Acoustic, radio-frequency, infrared, and optical countermeasures are discussed. PREREQUISITES: EE 4433, U.S. Citizenship and SECRET Clearance.

EE 4482 SIGNALS INTELLIGENCE (SIGINT) SYSTEMS ENGINEERING (2-2). This course covers airborne, shipboard, and ground based intercept and direction finding system techniques used against simple and sophisticated electromagnetic radiation systems. Among the topics covered are current state of the art for wideband and directional antennas, wideband RF preamplifiers, scanning and chirping receivers, displays, recorders, pattern recognizers and signal analysis devices. The laboratory periods are largely devoted to the specification and block diagram of systems to handle specified SIGINT tasks. PREREQUISITE: EE 4481 or permission of Instructor. U.S. Citizenship and SECRET Clearance are required.

EE 4491 NUCLEAR REACTOR CONTROL SYSTEMS (3-0). The nonlinear reactor kinetic equations are analyzed under controlled and accidental input conditions. The small-signal input method is used and the zero-power and power-to-reactivity feedback transfer functions are obtained. The requirements for stable and accurate operation of automatic flux control are established using linear feedback control theory. Digital computer methods of simulating the non-linear system are used to check on the validity of the linear theory. Modern control theory application to nuclear reactor systems is introduced. PREREQUISITE: EE 4412.

EE 4541 SIGNAL PROCESSING (3-1). Application of statistical decision theory to the detection of signals in noise. Ambiguity diagrams for signal detection and parameter estimation; signal design. Applications to antenna and transducer arrays. Signal processing in detection and tracking systems. PREREQUISITE: EE 4571.

EE 4571 STATISTICAL COMMUNICATION THEORY (3-2). This course is a more advanced sequel to EE 2114 than EE 3116. Basic concepts of information theory are introduced and their significance for communication systems is discussed. A study of noise sources and a mathematical treatment of noise and random signals based on statistical methods are presented. Transmission of such signals through linear and non-linear networks is analyzed. Statistical decision theory applications to signal detection and interpretation are illustrated by selected problems. PREREQUISITES: EE 2114 and PS 3411.

EE 4581 INFORMATION THEORY (3-1). Concepts of information measure for discrete and continuous signals. Fundamental theorems relating to channel capacity and coding; coding methods. Effects of noise on information transmission. Selected applications of the theory to systems. PREREQUISITE: EE 4571.

EE 4623 ADVANCED ELECTROMAGNETIC THEORY (3-2). A study of topics in microwave theory including perturbational and variational techniques, coupled mode theory, microwave integrated circuits, ferrites and topics from the current literature. PREREQUISITES: EE 3622.

EE 4631 ANTENNA THEORY AND APPLICATIONS (3-2). Basic wire and aperature radiator principles and array theory are presented. Modern antenna applications include adaptive and log-periodic structures. Laboratory exercises demonstrate input impedance and radiation pattern measurements. PREREQUISITE: EE 3622.

EE 4671 PROPAGATION (3-0). Properties of the earth and its atmosphere and the effect on radiowave propagation from ELF through millimeter wavelengths. Topics include noise, scatter, coverage predictions and frequency selection. Use is made of engineering nomograms and computer methods. PREREQUISITE: EE 3622 or permission of Instructor.

EE 4823 ADVANCED DIGITAL COMPUTER SYSTEMS (3-1). A course intended to acquaint the student with recent developments in digital systems as found in the research publications of the profession. Topics are selected at the discretion of the instructor and may include such subjects as: machine organization, computer graphics, man-machine interfaces, design automation, parallel processing, etc. An individually planned laboratory program is directed toward an experimental project involving state-of-the-art utilization of computer hardware or software. PREREQUISITE: EE 3812.

EE 4900 SPECIAL TOPICS IN ELECTRICAL ENGINEERING (2-0 to 5-0). Supervised study of the periodicals in selected areas of electrical engineering to meet the needs of the individual student. A written report is required at the end of the quarter. PREREQUISITE: Consent of the Department Chairman.

ENGINEERING ACOUSTICS

The Engineering Acoustics program is carried out as an inter-disciplinary effort with courses drawn principally from the fields of electrical engineering and physics. The emphasis is on those aspects of acoustics concerning propagation of sound in water, in applications of underwater sound, and on the electrical engineering of instrumentation for underwater sound detection.

Students interested in attaining a master's degree in Engineering Acoustics should consult with the Chairman of the Engineering Acoustics Committee, Professor John N. Dyer.

DEGREE REQUIREMENTS
MASTER OF SCIENCE IN ENGINEERING ACOUSTICS

1. A student pursuing a program leading to a Master of Science in Engineering Acoustics must have completed work which would qualify him for a Bachelor of Science degree in engineering or physical science. Credit requirement for the Master of Science degree must be met by courses in addition to those used to satisfy this requirement.

2. The Master of Science in Engineering Acoustics requires a minimum of 36 graduate credit quarter hours of course work; at least 20 graduate quarter hours must be taken in acoustics and its applications. One 4000 level course from each of three of the following areas must be included: wave propagation, vibration and noise control, transducer theory, sonar systems, and signal processing.

3. An acceptable thesis must be completed.

ENGINEERING SCIENCE
BACHELOR OF SCIENCE IN ENGINEERING SCIENCE

1. The following are the minimum requirements for the degree Bachelor of Science in Engineering Science.

2. The degree in Engineering Science requires a minimum of 100 quarter hours in Engineering and Science of which at least 50 hours must be in the upper division level.

3. The following specific requirements must be met. Areas marked with an asterisk must include laboratory work:

	Approximate Quarter Hrs.
a. Mathematics through calculus	17
b. Chemistry and Material Science*	15
c. Classical and modern Physics	16
d. Electrical Engineering including Electronics*	14
e. Mechanical Engineering including Mechanics and Thermodynamics	11
f. Probability and Statistics	3
g. Computers and Data Processing	4
h. Electives in Engineering and Science	20
	100

Electives will be chosen from courses in Mathematics, Chemistry or Physics, Electrical Engineering, Mechanical Engineering, Probability and Statistics, Computer Science, Oceanography, Meteorology, Operations Analysis.

Entrance to the Commissioned Officers and Faculty Club

DEPARTMENT OF GOVERNMENT AND HUMANITIES

BOYD FRANCIS HUFF, Professor of Government and History; Chairman, (1958)*; B.A., Univ. of Washington, 1938; M.A., Brown Univ., 1941; Ph.D., Univ. of California, 1955.

JOHN WILLIAM AMOS, II, Assistant Professor of Political Science (1970); B.A., Occidental College, 1957; M.A., Univ. of California at Berkeley, 1962; Ph.D., 1972.

LOFTUR L. BJARNASON, Professor of Literature (1958); A.B., Univ. of Utah, 1934; A.M., Harvard Univ., 1939; Ph.D., Stanford Univ., 1951.

WILLIAM CLAYTON BOGGESS, Associate Professor of Speech (1956); B.S., Univ. of Southern California, 1953; M.S., 1954.

DAN EDWARD CALDWELL, Lieutenant (junior grade), U. S. Naval Reserve; Instructor in Political Science (1971); A.B., Stanford Univ., 1970; M.A., Tufts Univ., 1971.

BARBARA BENNETT GABEL, Associate Professor of English (1967); A.B., Dickinson College, 1945; A.M., Peabody College, 1946; Ph.D., Univ. of North Carolina, 1954.

STEPHEN GOTTSCHALK, Assistant Professor of History (1968); B.A., Occidental College, 1962 M.A., Univ. of California at Berkeley, 1963; Ph.D., 1968.

JAMES MICHAEL MCADAMS, Lieutenant (junior grade), U. S. Naval Reserve; Instructor in Political Science (1969); B.A., Univ. New Mexico, 1967; M.A., 1968.

LAWRENCE WARD PEARSON, Lieutenant (junior grade), U. S. Naval Reserve; Instructor in Political Science (1969); B.A., Univ. of Maryland, 1967; M.A., Indiana Univ., 1968.

GEORGE ALFRED ROSS, JR., Lieutenant (junior grade), U. S. Naval Reserve; Instructor in Political Science and History (1972); B.A., Dartmouth College, 1969; M.A., Univ. of Pennsylvania, 1970; Ph.D. (pending).

BURTON MACLYNN SMITH, Associate Professor of Speech (1955); B.A., Univ. of Wisconsin, 1936; M.A., 1937.

RUSSEL HENRY STOLFI, Associate Professor of History (1966); B.S., Stanford Univ., 1954; M.A., 1964; Ph.D., 1966.

FRANK MICHAEL TETI, Associate Professor of Political Science (1966); B.A., Los Angeles State College, 1960; M.A., 1962; Diploma, Institute of World Affairs, 1961; Ph.D., Syracuse Univ., 1966.

EMERITUS FACULTY

EMMETT FRANCIS O'NEIL, Professor Emeritus (1958); A.B., Harvard Univ., 1931; M.A., Univ. of Michigan, 1932; Ph.D., 1941.

* *The year of joining the Postgraduate School Faculty is indicated in parentheses.*

LABORATORY FACILITY

The SPEECH LABORATORY is equipped with a closed circuit television and video-tape machine and has three cameras that provide a total of seven camera angles for speakers to be video-taped during classroom exercises. It is also equipped with a solid state sound system that is built into a lightweight adjustable lectern. A visual aids room adjoining the laboratory enables the speaker to use many types of audio-visual aids to support his speech.

Work is now being done with classes in conference dynamics which allows both instant replay and the compiling of data for future study and illustration in this area.

DEPARTMENTAL REQUIREMENTS FOR THE DEGREE BACHELOR OF ARTS WITH MAJOR IN GOVERNMENT (INTERNATIONAL RELATIONS)

For the award of the degree of Bachelor of Arts with major in Government (International Relations) a minimum of 44 hours of upper division courses in Government is required. Required courses include 12 hours in political theory, 12 hours in government, 8 hours in international relations, and 12 hours in comparative government. Course sequences and prerequisites shall be as prescribed by the Department of Government and Humanities.

ENGLISH

EN 0110 READING IMPROVEMENT (0-5). A course to improve the student's reading speed and comprehension. Associated areas involved in reading are stressed, especially vocabulary-buildup, study habits, and composition.

EN 0111 REVIEW OF THE FUNDAMENTALS OF GRAMMAR AND MECHANICS (1-1). A special course designed to extend the student's command of the principles of standard English usage.

Lower Division Course

EN 1010 FUNDAMENTALS OF WRITING (4-0). The fundamentals of grammar and rhetoric with practice in writing.

Upper Division Courses

EN 2010 ADVANCED WRITING (3-0). Intensive writing experience with the grammatical and rhetorical principles underlying sound expository and argumentative prose. PREREQUISITE: Freshman English or permission of Chairman of Department.

EN 2239 or EN 3239 DIRECTED STUDIES IN WRITING (Credit open). This course is designed to give editorial advice and assistance on an individual basis to students with writing projects in progress. PREREQUISITE: Permission of Chairman of Department.

GOVERNMENT

Lower Division Courses

GV 1060 U.S. GOVERNMENT (4-0). American political institutions and processes, the Constitution, parties, interest groups, elections, and voting behavior, with special emphasis on current issues and problems.

GV 1368 AMERICAN LIFE AND INSTITUTIONS (3-0). American political institutions and the political, social, economic, and cultural aspects of American life. *Open only to Allied Officers.*

Upper Division Courses

GV 2061 AMERICAN NATIONAL SECURITY POLICY (4-0). A study in depth of American defense policy from 1900 to the present with special emphasis on the period since 1945. The development of a unified defense department, the roles and missions of the services, the defense budgetary process, and the relationship of defense to overall American foreign policy will be analyzed. Cold war strategies, weapons systems and their effect on national policy are examined. PREREQUISITES: Courses in U.S. Government and U.S. History. *(Graduate students register for GV 3061.)*

GV 2160 COMPARATIVE GOVERNMENT (4-0). An analytical and comparative study of the form and functioning of the major types of contemporary government with emphasis on the policy-making process. PREREQUISITE: GV 1060.

GV 2161 INTRODUCTION TO INTERNATIONAL RELATIONS (4-0). The relations of nations, including a consideration of the factors of national power and study of international interests, and organizations.

GV 2163 WESTERN POLITICAL THOUGHT (4-0). A study of the development of Western political thought with special emphasis on the modern era. The philosophy and ideology of the enlightenment, the nineteenth and early twentieth centuries, and the development of democratic and socialist theory. *(Graduate students register for GV 3163.)*

GV 2164 COMPARATIVE IDEOLOGIES (4-0). Analysis of the major ideological forces in contemporary world affairs and their effect upon foreign and defense policies. Special emphasis on Marxian political and social thought. Analysis and comparison on the concepts of democracy, socialism, and fascism. Use of primary source material. PREREQUISITE: A course (upper division or graduate) in the History of Western Philosophy or Political Theory. *(Graduate students register for GV 3164.)*

GV 2165 20th CENTURY SOCIAL AND POLITICAL THOUGHT (4-0). Analysis of leading ideas in American and European social and political thought of the 20th Century. Social and political aspects of pragmatism and existentialism: impact of sociology, psychology and anthropology on social and political thought; the interrelation of religious and political ideas and variant forms of recent political radicalism. *(Graduate students register for GV 3165.)*

GV 2262 THEORY AND PRACTICE OF INTERNATIONAL POLITICS (4-0). A theoretical systematic analysis of international relations and a study of the factors, organizational strategies, and techniques of international politics. PREREQUISITE: GV 2161 or equivalent. *(Graduate students register for GV 3262.)*

GV 2268 PROBLEMS OF GOVERNMENT AND SECURITY IN CONTEMPORARY EUROPE (4-0). Problems of the European political system which have developed from World War II. Emphasis on the changing political roles and interests of the former European powers and the polarization into two competing security systems centered on Brussels (Washington) and Warsaw (Moscow). *(Graduate students register for GV 3268.)*

GV 2272 AMERICAN TRADITIONS AND THE NATIONAL INTEREST (4-0). A study of the ideals and values which constitute the essential qualities of American life. The main purpose of this course is to define the American national interest in the international context and the effect of national security policy on the realization of national goals. Course is designed to develop a capacity for problem analysis or to encourage opportunities for specialization of research. PREREQUISITE: Course in American history or American government desirable. *(Graduate students register for GV 3272.)*

GV 2273 PROBLEMS OF AMERICAN SECURITY AND FOREIGN POLICY (4-0). Underlying assumptions and objectives of security and foreign policy; domestic pressures; policy formation and instruments of policy; security treaties and alliance systems; role of diplomacy in peaceful solutions; and the role of force. *(Graduate students register for GV 3273.)*

GV 2279 DIRECTED STUDIES IN GOVERNMENT (Credit open). Independent study in government in subjects in which formal course work is not offered. PREREQUISITE: Permission of Chairman of Department. *(Graduate students register for GV 3279.)*

GV/PH 2280 NUCLEAR WEAPONS AND FOREIGN POLICY (4-0). An interdisciplinary course which covers both the technology and political influences of nuclear weapons systems. The course will emphasize the interaction of nuclear weapons systems with the foreign policies of the major powers and political blocs from 1945-present.

GV 2300 PROBLEMS OF GOVERNMENT AND SECURITY IN THE MIDDLE EAST (4-0). An intensive study of social, cultural, and political aspects of the contemporary Middle East. Special attention is paid to the interaction of inter-Arab and international politics; the emergence and spread of nationalist ideologies and their consequences for major power strategies in the area. *(Graduate students register for GV 3300.)*

GV 2310 NORTH AFRICA: PROBLEMS OF GOVERNMENT AND SECURITY IN THE MAGHREB (4-0). Security and politics of the countries of North Africa and the Red Sea Littoral. The countries dealt with are Libya, Sudan, Ethiopia, Somalia, Algeria, Tunisia, and Morocco. This course is designed to extend the student's knowledge of these countries and to provide some insight into the security problems presented by their domestic politics. PREREQUISITE: Completion of the basic course in Middle Eastern politics would be preferred but is not required. *(Graduate students register for GV 3310.)*

GV 2320 INTERNATIONAL RELATIONS AND SECURITY PROBLEMS IN THE MIDDLE EAST (4-0). The course focuses on selected problems affecting American security interests in the Middle East: Strategic waterways, including the Suez Canal, the Turkish Straits, and the Indian Ocean; the politics and problems of access to the area's oil resources; the development of U.S. and Soviet policies toward the area. The foregoing problems will be set in the context of inter-Arab politics. PREREQUISITE: Completion of the first course in Middle Eastern Politics or consent of Instructor. *(Graduate students register for GV 3320.)*

GV 2400 PROBLEMS OF GOVERNMENT AND SECURITY IN THE SOVIET UNION (4-0). A study of cultural, social, economic, and political characteristics of the Soviet System and its role in international security affairs. Particular emphasis is given to recent changes in Soviet society and future trends in Soviet political development. *(Graduate students register for GV 3400.)*

GV 2410 SOVIET SECURITY AFFAIRS (4-0). An examination of the process by which Soviet security policy is made and executed, utilizing conflict models developed in the last few years. Particularly stressed will be the constraints on policy-making in the Soviet Union, the process by which defense priorities are established, and the manifestation of those priorities in specific instances of conflict in the contemporary world. PREREQUISITE: GV 2400 or permission of Instructor. *(Graduate students register for GV 3410.)*

GV 2500 PROBLEMS OF GOVERNMENT AND SECURITY IN THE CARIBBEAN AREA (4-0). A study of the political, economics, social, and cultural characteristics and the security

problems of the countries in the Caribbean Area. Included are Mexico, Central America, the Caribbean Island countries, the Guianas, Venezuela, and Colombia. *(Graduate students register for GV 3500.)*

GV 2510 PROBLEMS OF GOVERNMENT AND SECURITY IN SOUTH AMERICA (4-0). A study of the political, economic, social, and cultural characteristics and the security problems of the countries in South America, excluding the Guianas. *(Graduate students register for GV 3510.)*

GV 2520 PROBLEMS OF DIPLOMACY AND SECURITY IN LATIN AMERICA (4-0). A study of the political, economic, and military relationships among the Latin American nations, and the role of Latin America in World politics. Special emphasis is placed on U.S. relations with Latin America. PREREQUISITE: GV 2500 or GV 2510 desirable. *(Graduate students register for GV 3520.)*

GV 2600 PROBLEMS OF GOVERNMENT AND SECURITY IN SOUTHEAST ASIA AND ADJACENT SEAS (4-0). Problems of modernization and revolution in the governments and economies of the states of Southeast Asia; cultural determinants; problems of ethnic minorities; role of religions; nationalism; communism and wars of liberation; the overseas Chinese problem; strategic interests of the major powers. *(Graduate students register for GV 3600.)*

GV 2610 PROBLEMS OF GOVERNMENT AND SECURITY IN EAST ASIA AND THE PACIFIC OCEAN (4-0). Problems of modernization, revolution, and conflict in the East Asian states. China's relations with contiguous states; Sino-Soviet state and party relations; esoteric Communist communication; ideological and strategic differences; Japan's new dynamic position; the U.S.-Japanese security problem; strategic interests of the major powers. *(Graduate students register for GV 3610.)*

GV 2620 PROBLEMS OF GOVERNMENT AND SECURITY IN SOUTH ASIA AND THE INDIAN OCEAN (4-0). Problems of nationalism, modernization, and security in the governments and economies of India, Pakistan, Afghanistan, and Ceylon. Indian-Pakistani relations; relations with China; the Tibetan and Kashmir problems; strategic interests of the major powers; Soviet interests and naval expansion in the Indian Ocean. *(Graduate students register for GV 3620.)*

Upper Division or Graduate Courses

Graduate Courses are designed to develop a capacity for problem analysis or to encourage opportunities for research specialization. All students should consult with the instructor before enrolling in any graduate course.

GV 3061 AMERICAN NATIONAL SECURITY POLICY (4-0). *(See GV 2061.)*

GV 3163 WESTERN POLITICAL THOUGHT (4-0). *(See GV 2163.)*

GV 3164 COMPARATIVE IDEOLOGIES (4-0). *(See GV 2164.)*

GV 3165 TWENTIETH CENTURY SOCIAL AND POLITICAL THOUGHT (4-0). *(See GV 2165.)*

GV 3262 THEORY AND PRACTICE OF INTERNATIONAL POLITICS (4-0). *(See GV 2262.)*

GV 3268 PROBLEMS OF GOVERNMENT AND SECURITY IN CONTEMPORARY EUROPE (4-0). *(See GV 2268.)*

GV 3272 AMERICAN TRADITIONS AND THE NATIONAL INTEREST (4-0). *(See GV 2272.)*

GV 3273 PROBLEMS OF AMERICAN SECURITY AND FOREIGN POLICY (4-0). *(See GV 2273.)*

GV 3279 DIRECTED STUDIES IN GOVERNMENT (Credit open). *(See GV 2279.)*

GV 3300 PROBLEMS OF GOVERNMENT AND SECURITY IN THE MIDDLE EAST (4-0). *(See GV 2300.)*

GV 3310 NORTH AFRICA: PROBLEMS OF GOVERNMENT AND SECURITY IN THE MAGHREB (4-0). *(See GV 2310.)*

GV 3320 INTERNATIONAL RELATIONS AND SECURITY PROBLEMS IN THE MIDDLE EAST (4-0). *(See GV 2320.)*

GV 3400 PROBLEMS OF GOVERNMENT AND SECURITY IN THE SOVIET UNION (4-0). *(See GV 2400.)*

GV 3410 SOVIET SECURITY AFFAIRS (4-0). *(See GV 2410.)*

GV 3500 PROBLEMS OF GOVERNMENT AND SECURITY IN THE CARIBBEAN AREA (4-0). *(See GV 2500.)*

GV 3510 PROBLEMS OF GOVERNMENT AND SECURITY IN SOUTH AMERICA (4-0). *(See GV 2510.)*

GV 3520 PROBLEMS OF DIPLOMACY AND SECURITY IN LATIN AMERICA (4-0). *(See GV 2520.)*

GV 3600 PROBLEMS OF GOVERNMENT AND SECURITY IN SOUTHEAST ASIA AND ADJACENT SEAS (4-0). *(See GV 2600.)*

GV 3610 PROBLEMS OF GOVERNMENT AND SECURITY IN EAST ASIA AND THE PACIFIC OCEAN (4-0). *(See GV 2610.)*

GV 3620 PROBLEMS OF GOVERNMENT AND SECURITY IN SOUTH ASIA AND THE INDIAN OCEAN (4-0) *(See GV 2620.)*

GV 3900 INTERNATIONAL ORGANIZATION (4-0). Analysis of the international system, its evolution from separatism and alliances to multinational organization and beyond. American goals, objectives, and resources are examined in bilateral relationships, regional groupings, functional approaches, and general organization. Collective security and peacekeeping efforts, pacific settlement, arms control and disarmament, and institution building. PREREQUISITES: Completion of three quarters in the Operations Research/Systems Analysis Curriculum, B average or better, and the consent of Instructor.

GV 3901 INTERNATIONAL POLICY ISSUES PERTAINING TO THE ENVIRONMENTAL SCIENCES (4-0). Examination of policy choices for the United States and other governments in the environment. Problems of national interest on developments in international law and organization. Relation of environmental sciences to international policy and security problems by the use of analytical techniques and the systems approach. PREREQUISITES: Completion of three quarters in Environmental Sciences or Operations Research/Systems Analysis curriculum, B average or better, and the consent of Instructor.

GV 3902 SCIENCE, TECHNOLOGY, AND PUBLIC POLICY (4-0). An inquiry into the role of science and technology in the formulation and conduct of national policy. Interactions between scientific communities, government, and military services on developments related to national and international security. Course is an elective for majors in departments of science or engineering. PREREQUISITES: Graduate standing, B average or better, with a major in the fields of science or engineering and the consent of Instructor.

HISTORY

Upper Division Courses

HI 2100 EUROPEAN HISTORY (1815-1914) (4-0). Foreign and domestic affairs of the major European states from the Congress of Vienna to the outbreak of the First World War.

HI 2101 EUROPEAN HISTORY (1914-1945) (4-0). Foreign and domestic affairs of the major European states from the First World War through the immediate aftermath of the Second World War.

HI 2201 U.S. HISTORY (1763-1865) (4-0). A survey of the political, economic, and social history of the United States from the Colonial Period to the end of the Civil War.

HI 2202 U.S. HISTORY (1865-1945) (4-0). A survey of the political, economic, and social history of the United States from Reconstruction to the end of World War II.

HI 2203 CONTINUITY AND CHANGE IN RECENT AMERICA (4-0). Analysis of major developments in American life since 1945. Emphasis on change in the political and corporate structure; impact of national security affairs on American values; new artistic and intellectual currents; problems of race, technology, and education. *(Graduate students register for HI 3203.)*

HI 2239 DIRECTED STUDIES IN HISTORY (Credit open). Independent study in history in which formal course work is not offered. PREREQUISITE: Permission of Chairman of Department. *(Graduate students register for HI 3239.)*

Upper Division or Graduate Courses

Graduate courses are designed to develop a capacity for problem analysis or to encourage opportunities for research specialization. All students should consult with the instructor before enrolling in any graduate course.

HI 3032 HISTORY OF RECENT INSURGENCY WARFARE (4-0). Study of the more important insurgencies in recent history from the Russian Revolution of 1917 to the more recent uprisings on five major continents. The study covers the selected insurgencies in detail emphasizing the general historical forces operating, e.g., Nationalism, Socialism, Imperialism, etc., as well as the particular forms of development. Emphasis will be on accurate description of events in order to derive patterns of insurgency warfare.

HI 3203 CONTINUITY AND CHANGE IN RECENT AMERICA (4-0). *(See HI 2203.)*

HI 3239 DIRECTED STUDIES IN HISTORY (Credit open). *(See HI 2239.)*

LITERATURE

Lower Division Course

LT 1040 APPRECIATION OF LITERATURE (4-0). A study of selected works of literature. The selection is intended to enhance the student's understanding and appreciation of literature as the most commonly used vehicle in expressing the aspirations, the hopes, and the enduring problems of mankind.

Upper Division Courses

LT 2241 MASTERPIECES OF AMERICAN LITERATURE (4-0). A study of Puritanism, the Enlightenment, Romanticism, and Naturalism as these intellectual trends are found in the works of representative American writers. PREREQUISITE: LT 1040.

LT 2242 MASTERPIECES OF BRITISH LITERATURE (4-0). A study of British literature with its cultural and historical implications. A modified survey approach is used, but selected works and authors are studied in some depth. PREREQUISITE: Same as for LT 2241.

LT 2243 MASTERPIECES OF EUROPEAN LITERATURE (4-0). A study of selected masterpieces of European literature. An effort is made to impress the student with the continuity of the Western European intellectual heritage. PREREQUISITE: LT 1040 or permission of Chairman of the Department.

PSYCHOLOGY

Upper Division Courses

PY 2050 GENERAL PSYCHOLOGY (4-0). A study of principles of rational and emotional processes in human thought and action.

PY 2251 APPLIED SOCIAL PSYCHOLOGY (4-0). An application of psychological principles to problems of personality growth, motivation, and interpersonal relations. PREREQUISITE: PY 2050 or permission of Chairman of Department.

SPEECH

Lower Division Course

SP 1020 PUBLIC SPEAKING (4-0). Practice in preparing and delivering extemporaneous speeches, emphasizing principles and techniques of oral style.

Upper Division Courses

SP 2020 COMMUNICATION MODELS FOR STAFF BRIEFING (4-0). Theoretic communication models applied to staff briefing. Practice in message analysis and design, presentation techniques/materials, intepersonal communication and persuasion with VTR feedback. The student must demonstrate research competence and creative application of theory. PREREQUISITE: SP 1020 or permission of Instructor.

SP 2021 STAFF SKILLS AND PROCEDURES (4-0). Staff study formats, investigation and data development, group procedures, oral presentation of completed staff study reports, group theory converted to classroom models. Emphasis upon completed staff work as an executive function. PREREQUISITE: SP 1020, staff experience, or permission of Instructor.

SP 2221 ADVANCED SPEECH (2-1). Practical application of techniques learned in SP 1020 with stress on composition, platform technique, audience situations, and audience response. Opportunity to address off-campus audiences is provided. PREREQUISITE: SP 1020 or equivalent. Enrollment limited.

Upper Division or Graduate Course

SP 3020 COMMUNICATION MODELS FOR STAFF BRIEFING (4-0). *(See SP 2020.)*

INTERDISCIPLINARY GROUP PROJECTS

OBJECTIVE — The group project has the objective of presenting the student with a complex problem which has to be solved by systems-oriented methods. It offers an alternative to the conventional research project which presents the student with a well-defined problem to be solved by science-oriented methods.

The group project represents a complex system which cannot be solved by an individual effort. Its solution requires team work of specialists from the early phases of problem definition and conceptual design until an optimum solution is presented in the final report. It involves application of fundamental principles and analytical methods to the solution of complex problems. It includes many aspects of a problem, including social, economic and political factors.

Such a group project provides the student with an opportunity to participate in a creative effort, to broaden his undersanding of real-life problems, and to become aware of the need for communicating with other disciplines.

DESCRIPTION — Participation in an Interdisciplinary Group project will be used in lieu of the thesis requirement for the Master of Science degree. Approval, on an individual basis, must be obtained in advance from the chairman of the student's major department. Enrollment in the project should occur in two consecutive quarters during the last three quarters of the sudent's program. The courses will be offered only if sufficient enrollment, a minimum of twelve, is obtained with representation from at least three disciplines.

It shall be the responsibility of the students to define the problem, develop a project management plan, solve the problem, and write the final report. The management plan shall account for:

a. group organization.

b. determination of problem solution goals and assignment of these goals to project members.

c. schedule of completion dates for the goals.

d. development of a format for weekly progress reports.

GROUP PROJECTS

GP 0910 ADVANCED PROJECT (4-0). This is the first of a two-course sequence in which students and faculty from three or more disciplines work together as a team to solve as completely as is feasible a specific problem. The purpose of the course is to offer students the opportunity to formulate and solve a complex problem of current interest using systems-oriented methods. The scope and details of the problem are defined by the faculty and students. PREREQUISITE: Permission of Department Chairman.

GP 0911 ADVANCE PROJECT (8-0). Continuation of GP 0910.

St. Thomas Aquinas Chapel was a parish project. A student wife created the copper crucifix behind the altar; another sculptured the Madonna of the Sea (not shown) and others made the corkboard Stations of the Cross and the banners. Pews from an abandoned church were trucked here by officer students and sons who sanded and painted them. Logs for the altar base came from trees cut down for the Navy golf course.

DEPARTMENT OF MATERIAL SCIENCE AND CHEMISTRY☆☆

JOHN HENRY DUFFIN, Professor of Chemical Engineering; Chairman (1962)*; B.S., Lehigh Univ., 1940; Ph.D., Univ. of California at Berkeley, 1959.

JOHN ROBERT CLARK, Professor of Metallurgy (1947); B.S., Union College, 1935; Sc.D., Massachusetts Institute of Technology, 1942.

GLEN ROBERT EDWARDS, Assistant Professor of Material Science (1971); B.S. in Met. Eng., Colorado School of Mines, 1961; M.S., Univ. of New Mexico, 1967; Ph.D., Stanford Univ., 1971.

CARL ADOLF HERING, Professor of Chemical Engineering (1946); B.S., Oregon State College, 1941; M.S., Cornell Univ., 1944.

RICHARD ALAN REINHARDT, Professor of Chemistry (1954); B.S., Univ. of California at Berkeley, 1943; Ph.D., 1947.

MELVIN FERGUSON REYNOLDS, Professor of Chemistry (1946); B.S., Franklin and Marshall College, 1932; M.S., New York Univ., 1935; Ph.D., 1937.

CHARLES FREDERICK ROWELL, Associate Professor of Chemistry (1962); B.S., Syracuse Univ., 1956; M.S., Iowa State Univ., 1959; Ph.D., Oregon State Univ., 1964.

JOHN WILFRED SCHULTZ, Associate Professor of Chemistry (1958); B.S., Oregon State College, 1953; Ph.D., Brown Univ., 1957.

JAMES EDWARD SINCLAIR, Professor of Chemical Engineering (1946); B.S., Ch. Eng., John Hopkins Univ., 1945; M.S., Naval Postgraduate School, 1956.

WILLIAM MARSHALL TOLLES, Associate Professor of Chemistry (1962); B.A., Univ. of Connecticut, 1958; Ph.D., Univ. of California at Berkeley, 1962.

JAMES WOODROW WILSON, Professor of Chemical Engineering (1949); B.A., Stephen F. Austin State, 1935; B.S., in Ch. E., Univ. of Texas, 1939; M.S., in Ch. E., Texas A & M College, 1941.

EMERITUS FACULTY

NEWTON WEBER BUERGER, Professor Emeritus (1942); B.S., Massachusetts Institute of Technology, 1933; M.S. 1934; Ph.D., 1939.

WILLIAM WISNER HAWES, Professor Emeritus (1952); B.S., Ch.E., Purdue Univ., 1924; Sc.M., Brown Univ., 1927; Ph.D., 1930.

GILBERT FORD KINNEY, Distinguished Professor Emeritus (1942); A.B., Arkansas College, 1928; M.S., Univ. of Tennessee, 1930; Ph.D., New York Univ., 1935.

GEORGE DANIEL MARSHALL, JR., Professor Emeritus (1946); B.S., Yale Univ., 1930; M.S., 1932.

GEORGE HAROLD MCFARLIN, Professor Emeritus (1948); B.A., Indiana Univ., 1925; M.A., 1926.

** The year of joining the Postgraduate School Faculty is indicated in parentheses.*

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LABORATORIES

The chemical laboratories provide facilities for undergraduate and graduate study and research in chemistry. Included for these purposes are: a radiochemistry ("hot") laboratory with Geiger and scintillation counters and special apparatus for handling and testing radioactive materials; a molecular spectroscopy laboratory, including infrared, ultraviolet, and magnetic resonance (ESR and NMR) spectrometers; a chemical instruments laboratory with infrared and ultraviolet spectrophotometers, vapor fractometers, refractometers, vapor pressure osmometers, polarographs, and other instruments commonly used for chemical determinations. A plastics laboratory is available for molding plastics and testing their mechanical properties. The department has an explosives laboratory with impact tester, ballistics mortar, chronograph and other apparatus for evaluating explosives. In the rocket propellent laboratory, small batches of solid propellents can be produced and many of the ballistic parameters and mechanical properties measured. Facilities are available for burning rate studies.

The materials laboratories are well equipped for both materials science and materials engineering studies and research. For these purposes standard universal testing machines, hardness testers, etc., are available for mechanical property determinations, plus a programable Instron testing instrument. For metallurgical studies the laboratory is equipped with heat-treating furnaces, metallographs, and microscopes. A plastics laboratory is available for evaluation of the mechanical, physical and chemical properties of plastics. Facilities for basic materials science studies include: several x-ray diffraction units; precision heating and powder cameras; Weissenberg x-ray unit; precision goniometers; recording photodensitometer, etc. Metal fabrication equipment includes welding facilities, a swaging machine, rolling mill, induction and vacuum melting furnaces and a die-casting matchine, and provides facilities for materials processing studies. A laboratory for high and low temperature studies of materials, including creep testing machines, afford additional modern equipment for materials research.

DEPARTMENTAL REQUIREMENTS FOR DEGREES IN CHEMISTRY OR MATERIAL SCIENCE

A specific curriculum should be consistent with the general minimum requirements for the degree as determined by the Academic Council.

Any program leading to award of a degree must be approved by the Department of Material Science and Chemistry at least two quarters before completion. In general, approved programs will require more than minimum degree requirements in order to conform to the needs and objectives of the United States Navy.

BACHELOR OF SCIENCE IN CHEMISTRY

1. A major in chemistry should include a minimum of 44 quarter hours of chemistry including required courses and electives, 17 quarter hours of physics (including general and modern physics), 18 quarter hours of mathematics (including differential equa-

tions), and 12 quarter hours of elective upper division courses in engineering, mathematics, or science.

2. The following specific requirements must be met. Courses marked with an asterisk must include laboratory work.

Subject	*Approximate Quarter Hours*
General*, inorganic*, analytical* chemistry, and instrumental analysis*	14
Organic chemistry*	9
Physical chemistry* and Thermodynamics	12
Chemistry electives, upper division	9

MASTER OF SCIENCE IN CHEMISTRY

1. To obtain a degree, Master of Science in Chemistry, the student must have completed work equivalent to the Bachelor of Science requirements of this department, with the exception of the electives.

2. In addition the student must successfully complete the following with a grade point average of 3.0 in all chemistry courses:

a. One graduate course in each of the following areas: Statistical Mechanics, Inorganic Chemistry, Physical-Organic Chemistry and Quantum Chemistry. Minimum total quarter hours — 13.

b. Two or more additional courses at the 4000 level in chemistry. These courses must have a total of not less than six quarter hours of lecture and must be approved by the Department of Material Science and Chemistry. Minimum total quarters hours — 6.

c. A thesis demonstrating ability to perform independent and original work and requiring a research effort equivalent to at least half-time for three quarters.

d. Sufficient supporting courses in science, mathematics and engineering to meet school requirements.

MASTER OF SCIENCE IN MATERIAL SCIENCE

1. The following is a statement of departmental minimum requirements for the degree of Master of Science in Material Science. A candidate shall previously have satisfied the requirements for a Bachelor's degree with a major in science or engineering. Credit requirements in succeeding paragraphs must be met by courses in addition to those used to satisfy this requirement.

2. A minimum credit of 16 quarter hours in 4000 level courses in Material Science is required. These shall include at least one course each in the areas of metals, ceramics, and plastics. A minimum of 10 quarter hours of graduate credit must be earned outside the major department. A total of at least 20 quarter hours of 4000 level courses must be included in the program.

3. Completion of a thesis and its acceptance by the department are required. A maximum of 7 quarter hours of graduate credit may be allowed toward satisfaction of the School requirement of 40 quarter hours, but the thesis credit may not be used to satisfy the requirements of paragraph 2.

CHEMISTRY AND CHEMICAL ENGINEERING

CH 0110 REFRESHER CHEMISTRY (4-0). Review of basic concepts of Chemistry. Topics include chemical bonding, stoichiometry, solutions, kinetics, equilibria, pH, and electrochemistry. Text: Sienko and Plane, *Chemistry, 3rd ed.* PREREQUISITE: None.

CH 0800 CHEMISTRY SEMINAR (0-1). A departmental program in which invited speakers and resident faculty speak on current topics in chemistry, material science and related areas. Students majoring in either chemistry or material science will report on their research and may also be requested to report on assigned topics from the literature. PREREQUISITE: None.

CH 0810 THESIS RESEARCH (0-0). Every student conducting thesis research will enroll in this course.

Lower Division Courses

CH 1001 INTRODUCTORY GENERAL CHEMISTRY I (4-2). The first quarter course of a two quarter sequence for students who have not had college chemistry. A study of the principles which govern the physical and chemical behavior of matter. TEXT: Sienko and Plane, *Chemistry, 3rd ed.*

CH 1002 INTRODUCTORY GENERAL CHEMISTRY II (3-2). The second squarter of a two-quarter sequence for students who have not had chemistry before coming to the Postgraduate School. TEXT: Same as CH 1001. PREREQUISITE: CH 1001.

Upper Division Courses

CH 2001 GENERAL PRINCIPLES OF CHEMISTRY (3-2). A study of the fundamental principles of chemistry governing the physical and chemical behavior of matter. Current theories of atomic structure and chemical bonding are particularly emphasized. Also studied are the states of matter and chemical equilibria. Special attention is given to the compounds of carbon. Elementary physical chemistry experiments are performed in the laboratory. TEXT: Mahan, *University Chemistry.* PREREQUISITE: College Chemistry.

CH 2101 INORGANIC ANALYSIS (3-3). A continuation of CH 2001. Computations involving acid-base, solubility, and complex ion equilibria. Principles of quantitative analysis. Descriptive inorganic chemistry. Laboratory work will consist of gravimetric and volumetric analysis. TEXT: Skoog and West, *Fundamentals of Analytical Chemistry;* Mahan, *University Chemistry.* PREREQUISITE: CH 2001 or CH 1002.

CH 2102 INORGANIC CHEMISTRY (3-3). Redox reactions and the electrode potential. Introduction to reaction mechanism. Bonding in inorganic species. Acids and bases. Laboratory will make use of qualitative, semi-quantitative, and instrumental methods to study the principles further, especially as applied to the solution chemistry of the metals. TEXT: Douglas and McDaniel, *Concepts and Models of Inorganic Chemistry.* PREREQUISITES: CH 2101 and CH 2402.

CH 2201 CHEMICAL INSTRUMENTS (3-3). A course designed to familiarize the student with modern instrumental techniques of chemical analysis. Emphasis is given to the theoretical basis of the various kinds of measurements made in the laboratory and the principles involved in the design and construction of analytical instruments. Laboratory experiments will deal with representative analytical problems. TEXTS: Ewing, *Instrumental Methods of Chemical Analysis, 4th ed.;* Silverstein and Bassler, *Spectrometric Identification of Organic Compounds, 2nd ed.* PREREQUISITES: CH 2101 and CH 2403.

CH 2301 ORGANIC CHEMISTRY I (4-3). The first quarter of a two quarter study of the chemistry of organic compounds. TEXT: Roberts and Caserio, *Basic Principles of Organic Chemistry.* PREREQUISITE: CH 2402. (May be taken concurrently.)

CH 2302 ORGANIC CHEMISTRY II (3-3). A continuation of CH 2301. The study of Organic Chemistry is pursued further with emphasis in the laboratory on synthetic techniques. TEXT: Roberts and Caserio, *Basic Principles of Organic Chemistry.* PREREQUISITE: CH 2301.

CH 2401 CHEMICAL THERMODYNAMICS (3-0). The laws of thermodynamics and their applications to chemical systems. Use is made of the chemical potential in describing multicomponent systems and the conditions for thermodynamic equilibrium. TEXT: Sheehan, *Physical Chemistry, 2nd ed.* PREREQUISITE: Differential Equations.

CH 2402 PHYSICAL CHEMISTRY I (3-3). Further applications of thermodynamics to chemical systems, colligative properties, chemical equilibrium, chemical kinetics, and electrochemistry. TEXT: Sheehan, *Physical Chemistry, 2nd ed.*; Daniels et al., *Experimental Physical Chemistry, 7th ed.* PREREQUISITE: CH 2401.

CH 2403 PHYSICAL CHEMISTRY II (4-3). Introduction to quantum chemistry, molecular structure, crystals, statistical mechanics, and reaction rate theory. TEXTS: Sheehan, *Physical Chemistry, 2nd ed.*; Daniels, et al., *Experimental Physical Chemistry, 7th ed.* PREREQUISITE: CH 2402.

CH 2705 PLASTICS AND HIGH POLYMERS (2-2). A study of the general nature of plastics and high polymers. This includes the correlation between properties and chemical structure. In the laboratory plastics are made, molded, tested and identified. TEXTS: Golding, *Polymers and Resins;* Kinney, *Engineering Properties and Application of Plastics.* PREREQUISITE: CH 2001.

Upper Division or Graduate Courses

CH 3101 ADVANCED INORGANIC CHEMISTRY (3-3). Coordination compunds and crystal field theory. Inorganic reaction mechanisms. The laboratory introduces the student to general methods for investigating chemical reaction. TEXT: Sykes, *Kinetics of Inorganic Reactions.* PREREQUISITES: CH 2102, CH 2403.

CH 3301 PHYSICAL ORGANIC I (3-0). First quarter of a two-quarter sequence. In this term the tools available for the study of organic mechanisms are discussed and appropriate examples used. TEXT: Gilliom, *Introduction to Physical Organic Chemistry.* PREREQUISITES: CH 2302, CH 3201.

CH 3401 CHEMICAL THEORY (4-0). An advanced one-term course concerned with topics in chemistry of special interest to physics majors. Topics include chemical bonding and quantum chemistry, symmetry of chemical systems and group theory, molecular spectroscopy, chemical equilibrium, rates of chemical reactions, and electrochemistry. TEXTS: Philips, *Basic Quantum Chemistry;* Moore, *Physical Chemistry, 3rd ed.* PREREQUISITES: College Chemistry, PH 3651, Matrix Mechanics and Thermodynamics.

CH 3403 CHEMICAL THERMODYNAMICS (3-0). Application of thermodynamics to real gases, non-electrolytes, electrolytic solutions, multicomponent solutions. Calculations of equilibria, estimation of thermodynamic quantities and brief discussion of calculations of thermodynamic properties from spectroscopic and other molecular data. TEXTS: Klotz, *Chemical Thermodynamics;* Lewis and Randall, *Thermodynamics, 2nd ed.* PREREQUISITE: CH 2402.

CH 3405 MOLECULAR DYNAMICS (5-0). Direct application of the Shroedinger wave equation to the hydrogen atom, angular momentum, matrix formulation of quantum mechanics, electron spin, the Pauli principle, interaction with electromagnetic radiation, development of group theory and application in quantum mechanics, and application of preceding framework to molecular hybridization, molecular orbital theory, ligand field theory, and vibrational spectra. TEXT: Pilar, *Elementary Quantum Chemistry.* PREREQUISITES: CH 2403, Matrix algebra.

CH 3415 STATISTICAL MECHANICS (4-0). A general treatment of the principles of quantum and classical statistical mechanics with applications to chemical systems. Included are distribution laws and the relationships of Fermi-Dirac, Bose-Einstein, and corrected Boltzmann statistics; statistical entropy and thermodynamic functions for corrected Boltzmann statistics; applications to chemical equilibria, diatomic and polyatomic molecules including ortho and para hydrogen; canonical and grand canonical ensembles; real gases. TEXT: Davidson, *Statistical Mechanics.* PREREQUISITE: CH 2403.

CH 3701 CONTROL ANALYSIS FOR CHEMICAL SYSTEMS (3-3). Introduction to the analysis and design of linear feedback control systems using illustrations based on chemical processes. Frequency response and Laplace transform methods are used and the state variable approach is presented. Derivation and analysis of process models is emphasized and systems set up and solved using digital and hybrid computers. PREREQUISITE: MA 2232.

CH 3705 REACTION MOTORS (3-0). A study of the fundamentals of rocket motors including a discussion of flight dynamics, mechanics, compressible flow, heat transfer, properties of solid and liquid propellants, design and performance parameters of solid, liquid and hybrid motors, and future developments. TEXTS: Sarner, *Propellant Chemistry;* Sutton, *Rocket Propulsion Elements.* PREREQUISITE: CH 2401.

CH 3709 EXPLOSIVES CHEMISTRY (3-2). Chemical and physical properties of explosives are related to modes of behavior and physical principles of use. Basic principles of testing and evaluation of explosives. Trends in new developments are surveyed. Independent exploratory work in the laboratory in such areas as manner of initiation, sensitivity, brisance, power, heats of explosion and combustion. TEXTS: Cook, *The Science of High Explosives;* Davis, *Chemistry of Powder and Explosives;* Rinehart and Pearson, *Explosive Working of Metals.* PREREQUISITE: CH 2001.

CH 3713 BLAST AND SHOCK EFFECTS (3-0). Generation of blast and shock waves by explosions, propagation of shock waves in air, scaling laws for explosions, shock and blast loads on structures, damage and damage mechanisms, thermal and ionizing radiation effects, principles of protection against damage. TEXT: Kinney, *Shocks in Air.* PREREQUISITES: CH 2401, CH 3401, or CH 2402.

CH 3717 UNIT OPERATIONS (3-2). An introduction to the study of the unit operations of chemical engineering. Selection of and primary emphasis on particular unit operations will be made on the basis of current student specialties. TEXTS: Foust et al., *Principles of Unit Operations;* Bird et al., *Transport Phenomena;* Smith and McCabe, *Unit Operations of Chemical Engineering.* PREREQUISITES: MA 1100, CH 2402, CH 2401.

Graduate Courses

CH 4302 PHYSICAL ORGANIC II (3-0). The techniques discussed in CH 3301 are used in the study of organic reaction mechanisms as currently understood. TEXT: See CH 3301. PREREQUISITE: CH 3301.

CH 4406 QUANTUM CHEMISTRY (3-0). A study of molecular spectra and molecular electronic structure, emphasizing theory, interpretation, and prediction of spectra utilizing the quantum mechanical formulation. PREREQUISITE: CH 3405.

CH 4410 CHEMICAL KINETICS (3-0). Experimental methods and interpretation of data. Collision theory and activated-complex theory. Mechanisms of reactions. TEXT: Frost and Pearson, *Kinetics and Mechanisms*. PREREQUISITE: CH 2403 and consent of Instructor.

CH 4505 RADIATION CHEMISTRY (3-0). A study of the theory behind the chemical processes occurring when ionizing and electromagnetic radiation interact with matter. Includes electronic states of molecules, introduction to photochemistry, properties of gaseous ions and free radicals, chain reactions. TEXTS: Spinks and Woods, *An Introduction to Radiation Chemistry*. PREREQUISITE: CH 3401 or CH 2403.

CH 4508 RADIO AND RADIATION CHEMISTRY (4-2). This course covers the subject outline for CH 4405 for three lectures of each week. The remaining lecture and laboratory covers the salient points of separation and handling of radioactive chemical systems. TEXT: Spinks and Woods, *An Introduction to Radiation Chemistry*. PREREQUISITES: CH 3401 or equivalent and nuclear physics (may be taken concurrently).

CH 4701 PROCESS CONTROL (3-2). A continuation of CH 3701 wherein complex control systems are studied. These include valves and transmission lines, heat exchangers, level control, flow control, control of distillation columns and chemical reactors and finally blending and pH control. Sampled data systems and optimization techniques are considered. TEXTS: Harriott, *Process Control;* Coughanowr and Koppel, *Process Control*. PREREQUISITE: Common Control Course (CH 3701).

CH 4709 APPLIED MATHEMATICS OF CHEMICAL ENGINEERING (3-2). The differential equations describing various chemical engineering processes are derived and solved using analytic and numeric techniques. Electronic computers will be used to obtain solutions to problems. TEXTS: Mickley et al., *Applied Mathematics in Chemical Engineering;* Wylie, *Advanced Engineering Mathematics*. PREREQUISITES: MA 1100, CH 2401, CH 2402.

CH 4800 SPECIAL TOPICS (2-0 to 4-0). Pursuit of deeper understanding of some topic chosen by the student and the instructor; may involve directed reading and conference or a lecture pattern. May be repeated for credit with a different topic. Typical topics are listed as follows:

(1) Chemical Engineering Kinetics
Chemical engineering applications with emphasis on large scale equipment design.

(2) Heat Transfer
Chemical engineering applications with emphasis on large scale and unusual equipment design.

(3) Natural Products
Study of degradation and synthesis of steroids, alkaloids and terpenes.

(4) Advanced Organic Chemistry
Study of new synthetic approaches in depth.

(5) Photochemistry
Chemical processes resulting from the interaction of electromagnetic radiation with matter.

(6) Inorganic Reaction Mechanisms
Theory and experiment concerning mechanisms of substitution and redox reaction for inorganic systems.

PREREQUISITE: Consent of the Instructor.

MATERIALS

MS 0810 THESIS RESEARCH (0-0). Every student conducting thesis research will enroll in this course.

Lower Division Courses

MS 1021 ELEMENTS OF MATERIALS SCIENCE I (3-2). An introduction to the nature and properties of materials for engineering applications. An essentially qualitative treatment of factors which govern the selection of materials. Classification of materials by type based on their chemical, physical and mechanical properties. Methods, processes and problems in the production of commercial materials. Introduction to crystal structure, phase equilibria, plastic deformation, recrystallization, grain growth, and precipitation hardening. TEXT: Van Vlack, *Elements of Materials Science, 2nd ed*. PREREQUISITE: CH 1001 or equivalent.

MS 1022 ELEMENTS OF MATERIALS SCIENCE II (2-2). Continuation of subject matter introduced in MS 1021 with stress on specific materials systems such as steel, plastics, and composites. Discussion of environmental factors and suggestions for avoiding or interpreting service failures. TEXT: Van Vlack, *Elements of Materials Science, 2nd ed*. PREREQUISITE: MS 1021.

Upper Division Courses

MS 2201 ENGINEERING MATERIALS (3-2). An introduction to the concepts of material science primarily for students in Mechanical Engineering. The concepts of atomic, crystal, micro- and macro-structure, their control and effects on chemical and physical properties will be emphasized. The role of defects is discussed. TEXT: Van Vlack, *Elements of Material Science*. PREREQUISITES: Elementary courses in physics and chemistry.

MS 2218 ELEMENTS OF ENGINEERING MATERIALS (3-2). The fundamental principles of materials science are presented, including a discussion of crystal structures, defects in crystal structures, phase equilibria, reaction rates and hardening mechanisms. Practical examples are discussed and included in laboratory exercises. TEXT: Van Vlack, *Elements of Material Science*. PREREQUISITES: Elementary courses in physics and chemistry.

MS 2228 INTRODUCTION TO ENGINEERING MATERIALS (3-2). A survey of engineering materials with emphasis upon applications in a marine environment. Microstructure, physical properties, environmental deterioration and materials selection are discussed. TEXT: Van Vlack, *Elements of Materials Science*. PREREQUISITES: Elementary courses in physics and chemistry.

Upper Division or Graduate Courses

MS 3202 PROPERTIES OF STRUCTURAL MATERIALS (3-2). The properties of structural materials are related to microstructure and defects. Topics of interest to the Naval engineer are selected, including iron, aluminum, and titanium alloys, high strength steels, welding and other joining techniques, and environmental deterioration. TEXT: Clark and Varney, *Physical Metallurgy for Engineers*. PREREQUISITE: MS 2201.

MS 3304 CORROSION (3-2). Presents the basic chemical, electrochemical, mechanical and metallurgical factors which influence the corrosion, oxidation and deterioration of materials. Discusses standard methods of corrosion control such as cathodic protection, coatings, cladding, alloy selection and inhibitors; special problems encountered in unfamiliar environments. TEXT: Uhlig, *Corrosion and Corrosion Control*. PREREQUISITE: MS 1022 or MS 3202.

Graduate Courses

MS 4206 THE STRUCTURE AND MECHANICAL PROPERTIES OF CRYSTALS (3-0). A discussion of dislocations in crystals and the mechanical properties to be expected in real crystals. The topics discussed include the forces between dislocations, stacking faults and partial dislocations, the generation of dislocations during crystal growth and during plastic deformation, the locking of dislocations. The experimental investigation of dislocations by optical methods, decorating techniques, electron transmission microscopy, and diffraction methods are discussed. TEXTS: Fridel, *Dislocations;* Weertman and Weertman, *Elementary Dislocation Theory;* Amelinck, *The Direct Observation of Dislocation.* PREREQUISITES: MS 3202.

MS 4215 PHASE TRANSFORMATIONS (3-4). The thermodynamics and kinetics of transformations in solids. The free energy of alloys, solidification, precipitation, recrystallization, diffusion and diffusionless transformations. Extensive individual initiative is allowed and expected in the laboratory. TEXTS: Reed-Hill, *Physical Metallury Principles;* Fine, *Introduction to Phase Transformations in Condensed Systems;* Wayman, *Introduction to the Crystallography of Martensite Transformation.* PREREQUISITE: MS 3202.

MS 4302 SPECIAL TOPICS IN MATERIAL SCIENCE (hours by arrangement). Independent study of advanced subjects not regularly offered. PREREQUISITE: Consent of the Instructor.

MS 4304 ENVIRONMENTAL DETERIORATION OF MATERIALS (3-3). The role of corrosive atmosphere, metallurgical structure, surface physics and stress state in leading to catastrophic embrittlement of high strength materials. Particular reference to stress corrosion, hydrogen embrittlement, liquid-metal embrittlement and corrosion fatigue. TEXTS: Fontana and Greene, *Corrosion Engineering;* Staehle, *Proceedings of the International Conference on Fundamental Aspects of Stress Corrosion Cracking.* PREREQUISITE: MS 3304.

MS 4305 MATERIALS FOR ELECTRICAL AND ELECTRONIC APPLICATIONS (3-0). The properties and preparation of materials used in electrical and electronic applications. Among the materials discussed are ferromagnetic materials, both hard and soft, ferrimagnetic materials, semiconductors, both elemental and compound, insulators and dielectrics, piezoelectric and ferroelectric crystals. The electronic, crystallographic and thermodynamic principles controlling these materials are discussed and the heat treatments, compositions and methods of fabrication of commercial materials are emphasized. TEXT: Nusbaum, *Electronic and Magnetic Behavior of Materials.* PREREQUISITE: MS 3202.

MS 4312 MATERIALS SYSTEMS (3-0). Attempts to establish criteria of standard environment and standard behavior of engineering materials. Examines properties of materials at extremes of temperature, rate and duration and frequency of loading, corrosive environment, and the conditions of outer space. Examines factors amenable to control at the molecular and structural levels and illustrates with real materials. Development of materials to meet requirements of extreme environmental conditions is illustrated by alloy steels, refractory metals and alloys, composites, cermets and special materials. TEXT: Dorn, *Mechanical Behavior of Materials at Elevated Temperatures.* PREREQUISITE: MS 3202.

MS 4320 PROPERTIES OF CERAMIC MATERIALS (4-0). Occurrences, syntheses and properties of ceramic raw materials. Kinetic and phase equilibrium principles underlying the production of ceramics and glasses. Structure of typical ceramics and glasses. TEXT: Kingery, *Introduction to Ceramics.* PREREQUISITE: CH 2402.

MS 4401 PHYSICS OF SOLIDS (3-0). A course intended for students particularly interested in material science and which will cover topics being developed in the literature but with emphasis on crystallographic and mechanical subjects such as order-disorder, symmetry and anti-symmetry, twinning, brittle fracture, transition temperatures, etc. TEXTS: Instructor's notes; current literature. PREREQUISITES: MS 4215 or PH 3651 or PH 4751.

MS 4811 MECHANICAL BEHAVIOR OF ENGINEERING MATERIALS (3-0). The response of single crystals and polycrystalline aggregates to mechanical stress. The plastic deformation and fracture of real materials including metals and alloys, ceramics and cermets, composites, and polymers. Fracture resulting from fatigue and environmental conditions will be discussed. Creep and Mechanical properties at elevated temperature will be described and current theories discussed. TEXT: Dieter, *Mechanical Metallurgy.* PREREQUISITES: MS 3202, Engineering Mechanics.

** As of press time, a decision has been made to disestablish this department on 30 June 1972. Courses and degrees in Chemistry and Material Science will continue to be offered under the cognizance of other departments.

DEPARTMENT OF MATHEMATICS

WALTER MAX WOODS, Professor of Mathematics and Statistics; Chairman (1961)*; B.S., Kansas State Teachers College, 1951; M.S., Univ. of Oregon, 1957; Ph.D., Stanford Univ., 1961.

DAVID ARTHUR AULT, Assistant Professor of Mathematics (1971); B.A., Western Washington State College, 1964; M.A., 1966; Ph.D., The Pennsylvania State Univ., 1970.

GERALD LEONARD BARKSDALE, JR., Assistant Professor of Mathematics (1967); B.S., Rice Univ., 1965; M. S., 1966.

ALAN PAUL BENDER, Lieutenant (junior grade), U. S. Naval Reserve; Instructor in Mathematics (1969); B.A., Univ. of Minnesota, 1967; M.S., 1968.

WILLARD EVAN BLEICK, Professor of Mathematics (1946); M.E., Stevens Institute of Technology, 1929; Ph.D., Johns Hopkins Univ., 1933.

ROBERT COY BOLLES, Lieutenant (junior grade), U. S. Naval Reserve; Instructor in Mathematics (1969); B.S., Yale Univ., 1967; M.S., Univ. of Pennsylvania, 1968.

RAYMOND HARVEY BRUBAKER, JR., Ensign, U. S. Naval Reserve; Instructor in Mathematics (1971); B.S., Univ. of California at Los Angeles, 1971; M.S., 1971.

JOHN JOSEPH BUDWAY, Lieutenant (junior grade), U. S. Naval Reserve; Instructor in Mathematics (1970); B.S., St. John's Univ., 1967; M.S., Pratt Institute, 1968.

WILLIAM CARROLL CHEWNING, JR., Lieutenant (junior grade), U. S. Naval Reserve; Assistant Professor of Mathematics (1970); B.A., Hampden-Sydney College, 1967; Ph.D., Univ. of Virginia, 1970.

CRAIG COMSTOCK, Associate Professor of Mathematics (1970); B.E.P., Cornell Univ., 1956; M.S., Naval Postgraduate School, 1961; Ph.D., Harvard Univ., 1965.

DANIEL LEE DAVIS, Assistant Professor of Mathematics (1969); B.S., Georgia Institute of Technology, 1965; Ph.D., California Institute of Technology, 1969.

DANNY RAY DIXON, Lieutenant (junior grade), U. S. Naval Reserve; Instructor in Mathematics (1969); B.S., Southern Methodist Univ., 1966; M.S., 1967.

RICHARD JEROME ESTELL, Lieutenant (junior grade), U. S. Naval Reserve; Instructor in Mathematics (1969); B.A., Univ. of Iowa, 1967; M.S., 1968.

ROBERT MICHAEL EVANS, Lieutenant, U. S. Naval Reserve; Assistant Professor of Mathematics (1971); B.A., Rice Univ., 1965; B.S., 1966; M.S., Stanford Univ., 1967; Ph.D., 1971.

FRANK DAVID FAULKNER, Professor of Mathematics (1950); B.S., Kansas State Teachers College, 1940; M.S., Kansas State College, 1942; Ph.D., Univ. of Michigan, 1969.

RICHARD HOMER FRANKE, Assistant Professor of Mathematics (1970); B.S., Ft. Hays Kansas State College, 1959; B.S., Univ. of Utah, 1961; Ph.D., 1970.

ROBERT EUGENE GASKELL, Professor of Mathematics (1966); A.B., Albion College, 1933; M.S., Univ. of Michigan, 1934; Ph.D., 1940.

JOSEPH GIARRATANA, Professor of Mathematics (1946); B.S., Univ. of Montana, 1928; Ph.D., New York Univ., 1936.

GREGORY DEAN GIBBONS, Assistant Professor of Mathematics (1970); B.A., Univ. of California at Santa Barbara, 1963.

ROBERT MARTIN HANNA, Lieutenant Commander, U. S. Navy; Instructor in Mathematics (1971); B.S., Univ. of Kansas, 1958; M.S., Naval Postgraduate School, 1966.

TOKE JAYACHANDRAN, Associate Professor of Mathematics (1967); B.S., V.R. College, Nellore, India, 1951; M.S., Univ. of Wyoming, 1962; Ph.D., Case Institute of Technology, 1967.

WALTER JENNINGS, Professor of Mathematics (1947); B.A., Ohio State Univ., 1932; B.S., 1932; M.A., 1934.

GARY ARLEN KILDALL, Assistant Professor of Mathematics (1969); B.S., Univ. of Washington, 1967; M.S., 1968.

UNO ROBERT KODRES, Associate Professor of Mathematics (1963); B.A., Wartburg College, 1954; M.S., Iowa State Univ., 1956; Ph.D., 1958.

BYRON LEWIS KOLITZ, Lieutenant, U. S. Naval Reserve; Instructor in Mathematics (1969); B.A., Vanderbilt Univ., M.S., Univ. of Florida, 1966.

LADIS DANIEL KOVACH, Professor of Mathematics (1967); B.S., Case Institute of Technology, 1936; M.S., 1948; M.A., Western Reserve Univ., 1940; Ph.D., Purdue Univ., 1951.

LEE GEORGE LITZLER, Lieutenant, U. S. Navy; Instructor in Mathematics (1969); B.A., Univ. of Texas, 1967; M.A., 1969.

KENNETH ROBERT LUCAS, Associate Professor of Mathematics (1958); B.S., Washburn Univ., 1949; Ph.D., Kansas Univ., 1957.

HERMAN BERNHARD MARKS, Associate Professor of Mathematics (1961); B.S., Southern Methodist Univ., 1950; M.A., Univ. of Texas, 1959.

GEORGE WILLIAM MORRIS, Professor of Mathematics (1968); B.A., Southwestern Institute of Technology, 1942; M.A., Univ. of Oklahoma, 1947; Ph.D., University of California at Los Angeles, 1957.

JOHN PHILIP PIERCE, Professor of Mathematics (1948); B.S. in E.E., Worcester Polytechnic Institute of Brooklyn, 1931; M.S.E.E., Polytechnic Institute of Brooklyn, 1937.

FRANCIS MCCONNELL PULLIAM, Professor of Mathematics (1949); B.A., Univ. of Illinois, 1937; M.A., 1938; Ph.D., 1947.

BART FRANCIS RICE, Lieutenant, U. S. Naval Reserve; Assistant Professor of Mathematics (1971); B.A., Rice Univ., 1965; M.S., Louisiana State Univ., 1967; Ph.D., 1969.

ALAN BRUCE ROBERTS, Lieutenant (junior grade), U. S. Naval Reserve; Instructor in Mathematics (1969); B.A., Univ. of Texas, 1967; M.A., 1969.

ARTHUR LORING SCHOENSTADT, Assistant Professor of Mathematics (1970); B.S., Rensselaer Polytechnic Institute, 1964; M.A., 1965; Ph.D., 1968.

ALAN MCKEAN SHORB, Assistant Professor of Mathematics (1968); B.A., Swarthmore College, 1960; M.A., Cornell Univ., 1965; Ph.D., Univ. of Minnesota, 1969.

SEYMOUR SINGER, Adjunct Professor of Mathematics (1971); B.A., Univ. of California at Los Angeles, 1954; M.A., Univ. of California at Berkeley, 1960; Ph.D., 1969.

ELMO JOSEPH STEWART, Professor of Mathematics (1955); B.S., Univ. of Utah, 1937; M.S., 1939; Ph.D., Rice Institute, 1953.

GLENN ALLEN STOOPS, Assistant Professor of Mathematics (1970); S.B., Massachusetts Institute of Technology, 1961; S.M., 1962; Ph.D., Rice Univ., 1967.

GORDON HENRY SYMS, Assistant Professor of Mathematics (1970); B.S., Univ. of Alberta, 1959; M.S., Univ. of Washington, 1964; Ph.D., 1967.

DONALD HERBERT TRAHAN, Associate Professor of Mathematics (1966); B.S., Univ. of Vermont, 1952; M.A., Univ. of Nebraska, 1954; Ph.D., Univ. of Pittsburgh, 1961.

PETER CHENG-CHAO WANG, Associate Professor of Mathematics (1970); B.A., Pacific Lutheran Univ., 1961; M.A., Wayne State Univ., 1962; Ph.D., 1966.

MAURICE DEAN WEIR, Assistant Professor of Mathematics (1969); B.A., Whitman College, 1961, M.S., Carnegie-Mellon Univ., 1963; D.A., 1970.

CARROLL ORVILLE WILDE, Associate Professor of Mathematics (1968); B.S., Illinois State Univ., 1958; Ph.D., Univ. of Illinois, 1964.

EMERITUS FACULTY

HORACE CROOKHAM AYRES, Professor Emeritus (1958); B.S., Univ. of Washington, 1931; M.S., 1931; Ph.D., Univ. of California at Berkeley, 1936.

CHARLES HENRY RAWLINS, JR., Professor Emeritus (1922); Ph.B., Dickinson College, 1910; M.A., 1913; Ph.D., Johns Hopkins Univ., 1916.

** The year of joining the Postgraduate School Faculty is indicated in parentheses.*

DEPARTMENTAL REQUIREMENTS FOR DEGREES IN MATHEMATICS

The Department of Mathematics offers a Bachelor of Science or a Master of Science degree to qualified students. An interested student should consult the Chairman of the Mathematics Department for an evaluation of his previous academic record to determine his potential for successfully completing a degree program.

If the student's previous record is found to be adequate, a mathematics program is designed which satisfies the Departmental requirements and fits the interest, preparation and aptitude of the student. The program, and subsequent changes in the program, must be approved by the Departmental Chairman.

BACHELOR OF SCIENCE DEGREE WITH MAJOR IN MATHMATICS

1. Of the total quarter hours specified in the general requirements for the degree of Bachelor of Science, a student majoring in mathematics must complete at least 30 quarter hours of approved course work in mathematics beyond calculus, and must have an average QPR of 2.25 or greater in these 30 quarter hours.

2. The following topics are specifically included in any major program. Courses listed in parentheses or their equivalents may be used to satisfy the requirements.

a. 6 hours of Analysis (MA 3605-3606)
b. 6 hours of Algebra (MA 3046-3047)
c. 4 hours of Differential Equations (MA 2121)
d. 3 hours of Complex Analysis (MA 2172)
e. 4 hours of Probability and Statistics (PS 2501)

MASTER OF SCIENCE DEGREE WITH MAJOR IN MATHEMATICS

1. In order to pursue a program leading to the Master of Science degree with major in mathematics, a student must have a background which would qualify him for a Bachelor of Science degree with major in mathematics, as stated above. A student whose background does not satisfy this requirement may take course work to eliminate this deficiency. However, such courses cannot be counted toward satisfying the Departmental requirements for the degree of Master of Science.

2. A curriculum which satisfies the Master of Science degree requirements consists of a minimum of 45 quarter hours of approved courses in mathematics and related subjects. An acceptable thesis may be counted as equivalent to nine quarter hours. A student must have a QPR of 3.0 or greater in the any major program.

3. At the discretion of the Chairman of the Department of Mathematics, a student pursuing a program leading to the Master of Science degree with major in mathematics may (or may not) be required to write a thesis in mathematics.

4. The following topics are specifically included in any major program:

a. 6 hours of Algebra
b. 6 hours of Analysis

5. The main areas for thesis topics are
   a. Computer Science
   b. Differential Equations
   c. Fourier Analysis
   d. Functional Analysis
   e. Numerical Methods
   f. Optimal Control
   g. Probability and Statistics
   h. Tensor Analysis and Applications

COMPUTER SCIENCE

Computer Science is an interdepartmental effort involving the Departments of Electrical Engineering and Mathematics. Complete descriptions of the following courses may be found on page 73.

CS 0001 SEMINAR (0-1).

CS 0110 FORTRAN PROGRAMMING (3-0).

CS 0810 THESIS RESEARCH (0-0).

Upper Division Courses

CS 2100 INTRODUCTION TO COMPUTERS AND FORTRAN PROGRAMMING (4-0)

CS 2103 INTRODUCTION TO COMPUTERS AND COBOL PROGRAMMING (4-0).

CS 2105 SURVEY OF COMPUTERS AND PROGRAMMING (4-0).

CS 2110 INTRODUCTION TO COMPUTERS AND PROGRAMMING FOR COMPUTER SCIENCE MAJORS (3-2).

Upper Division or Graduate Courses

CS 3111 FUNDAMENTAL CONCEPTS IN STRUCTURAL PROGRAMMING LANGUAGES (4-0).

CS 3112 OPERATING SYSTEMS (4-0).

CS 3200 STRUCTURE OF DIGITAL COMPUTERS (4-0).

CS 3201 COMPUTER SYSTEMS (4-0).

CS 3204 DATA COMMUNICATIONS (4-0).

CS 3300 INFORMATION STRUCTURES (3-0).

CS 3601 AUTOMATA AND FORMAL LANGUAGES (3-0).

CS 3800 DIRECTED STUDY IN COMPUTER SCIENCES (0-2 to 0-8).

Graduate Courses

CS 4113 COMPILER DESIGN AND IMPLEMENTATION (3-2).

CS 4202 INTERACTIVE COMPUTATION SYSTEMS (3-2).

CS 4310 NON-NUMERICAL INFORMATION PROCESSING (4-0).

CS 4900 ADVANCED TOPICS IN COMPUTER SCIENCE (3-0).

MATHEMATICS

MA 0110 REFRESHER MATHEMATICS (5-5). General category for those students who cannot be properly evaluated due to lack of transcript or questionable academic record.

MA 0111 REFRESHER MATHEMATICS (5-5). Operations Analysis refresher for students preparing to take MA 2109.

MA 0112 REFRESHER MATHEMATICS (5-5). Calculus review for students who need to validate MA 1100.

MA 0113 REFRESHER MATHEMATICS (5-5). Algebra review for students whose first course is MA 1021 or MA 2300.

MA 0114 REFRESHER MATHEMATICS (5-5). Pre-calculus review for students whose first course is MA 1120.

MA 0115 REFRESHER MATHEMATICS (5-5). General calculus review for students whose first course is MA 1100.

MA 0125 LOGIC AND SET THEORY (5-0). An introduction to the elements of set theory and mathematical reasoning. Sets, Venn diagrams, truth tables, quantifiers, logical reasoning. Functions, relations, partitions and equivalence relations, 1-1 correspondence. (Paradoxes of set theory, axiom of choice). PREREQUISITE: None.

MA 0810 THESIS RESEARCH (0-0). Every student conducting thesis research will enroll in this course.

Lower Division Courses

MA 1010 INTERMEDIATE ALGEBRA (4-0). The set of real numbers and postulates for the development of the algebra of real numbers. Proofs of some elementary theorems for the algebra of the real numbers. Applications of the postulates and theorems to addition, subtraction, multiplication, division and factoring of algebraic expressions. Application to word problems, first degree equations and equations of higher degree. Functions, graphs and inequalities. Exponents and logarithms. Sequences, series and the binomial theorem. Complex numbers. PREREQUISITE: None.

MA 1021 COLLEGE ALGEBRA AND TRIGONOMETRY (4-0). Brief review of algebraic fundamentals. Slide rule and logarithmic methods of computation. Algebra of complex numbers, quadratic equations. Systems of equations, determinants, Cramer's rule. Binomial theorem. Mathematical induction. Trigonometric functions of the general angle. Identities. Solution of right and oblique triangles. Elements of the theory of equations. PREREQUISITE: MA 1010 or equivalent.

MA 1100 CALCULUS REVIEW (4-0). Functions of one variable, limits, derivatives, continuity, indefinite and definite integrals, transcendental functions, Taylor's theorem; vectors in two and three dimensions, functions of several variables, partial derivatives, multiple integration. PREREQUISITE: A previous course in caluculus.

MA 1115 CALCULUS I (5-0). Introduction to plane analytic geometry, functions of one variable, limits, continuity, derivatives, indefinite and definite integrals, transcendental functions, conic sections, elementary vector algebra, vector differentiations. PREREQUISITE: Some previous work in calculus.

MA 1116 CALCULUS II (5-0). Polar coordinates, vector algebra and vector calculus in three dimensional space, functions of several variables, double and triple integrals, infinite series, introduction to differential equations. PREREQUISITE: MA 1115.

MA 1120 CALCULUS AND ANALYTIC GEOMETRY I (5-2). Introduction to plane analytic geometry, functions of one variable, limits, continuity, derivatives, indefinite and definite integrals, transcendental functions, conic sections, elementary vector algebra, vector differentiations. PREREQUISITE: MA 1021.

MA 1121 CALCULUS AND ANALYTIC GEOMETRY II (5-2). Polar coordinates, vector algebra and vector calculus in three dimensional space, functions of several variables, double and triple integrals, infinite series, introduction to differential equations. PREREQUISITE: MA 1115 or MA 1120.

Upper Division Courses

MA 2025 LOGIC, SETS AND FINITE MATHEMATICS (4-0). Propositional logic and elements of set theory. Relations, functions and partitions. Elements of finite probability theory. PREREQUISITE: None.

MA 2042 LINEAR ALGEBRA (4-0). Elementary matrix algebra. Vector spaces, linear dependence, basis, dimension, rank. Systems of linear equations. Determinants. Linear transformations, change of basis, characteristic equation, roots and vectors of a matrix. Special matrices: symmetric, orthogonal, inverse. Orthogonal reduction of a symmetric matrix. Inverse by partitioning. Introduction to quadratic forms. Cayley-Hamilton theorem. PREREQUISITE: MA 2109 should be taken concurrently.

MA 2045 INTRODUCTION TO LINEAR ALGEBRA (3-0). Complex numbers. Systems of linear algebraic equations. Matrix algebra. Vector spaces. Rank. Inverse by Gauss' method. Determinants. Adjoint and inverse. Characteristic equation, roots and vectors — proper axes for quadratic surface, solution of system of differential equations. Orthogonal reduction to diagonal form. PREREQUISITE: MA 1100 or equivalent.

MA 2047 LINEAR ALGEBRA AND VECTOR ANALYSIS (4-0). Systems of linear equations. Matrix algebra. Inverse by Gauss' method. Determinants. Adjoint and inverse. Vector spaces. Rank. Vector differential and integral calculus in rectangular and orthogonal curvilinear coordinate systems. PREREQUISITE: MA 1100 or equivalent.

MA 2109 MULTIVARIABLE CALCULUS (5-0). Integrated with linear algebra; this course may only be taken concurrently with MA 2042. Functions of several variables, extrema, continuous transformation, chain rules, implicit function theorems. multiple integrals and transformations of multiple integrals, Taylor's series. PREREQUISITE: Differential and integral calculus.

MA 2110 SELECTED TOPICS FROM ADVANCED CALCULUS (4-0). A selection of topics from Advanced Calculus, such as infinite series, differential equations, improper integrals, introduction to functions of a complex variable. PREREQUISITE: MA 2109 or equivalent.

MA 2121 DIFFERENTIAL EQUATIONS (4-0). Ordinary differential equations: homogeneous and non-homogenous equations, linear independence of solutions, linear and non-linear equations, power series solutions, systems of differential equations, applications. PREREQUITIES: MA 1100 or equivalent, MA 2045 or equivalent concurrently.

MA 2161 INTRODUCTION TO MATHEMATICAL PHYSICS (4-0). An introduction to the techniques used in solving problems in the classical field theories. Vector and scalar fields are studied. Solutions to the source-free equations most often encountered in physics are discussed. PREREQUISITES: MA 1110 and MA 2121 (the latter may be taken concurrently).

MA 2172 COMPLEX VARIABLES (4-0). Analytic functions, integration and series representations. Residue theory and application to Laplace transform. Conformal mapping and applications. PREREQUISITE: MA 2121 or equivalent.

MA 2232 NUMERICAL METHODS (3-1). Error propagation. Evaluation of functions. Nonlinear equations. Linear algebra for computers. Interpolation. Least squares approximation. Numerical integration. Ordinary differential equations. PREREQUISITE: MA 2121 and CS 0110 or equivalent.

MA 2300 MATHEMATICS FOR MANAGEMENT (5-0). This course is designed to provide the mathematical basis for modern managerial tools and techniques. It includes a review of algebra, systems of linear equations and linear inequalities, introductory material from linear programming, vectors and matrices, a brief survey of differential and integral calculus. PREREQUISITE: None.

MA 2301 MATHEMATICS FOR MANAGEMENT (3-0). This course is designed to provide the mathematical basis for modern managerial tools and techniques. It includes linear algebra, linear programming, vectors and matrices and applications of their fields as well as applications of one-dimensional and multi-dimensional differential and integral calculus to problems appropriate to business, economics, and management. PREREQUISITE: MA 1100 or equivalent.

Upper Division or Graduate Courses

MA 3026 TOPICS IN DISCRETE MATHEMATICS (4-0). Review of mathematical induction. Elements of number theory: divisibility, congruences and prime numbers. Generating functions and combinatorial problems. Elements of graph theory. PREREQUISITE: MA 2025.

MA 3042 LINEAR ALGEBRA (5-0). Systems of linear algebraic equations. Matrix algebra. Vector spaces. Rank. Inverse by Gauss' method. Determinants. Adjoint and inverse. Characteristic equation, roots, vectors — proper axes for a quadric surface, applications to systems of differential equations. Similarity to a diagonal matrix. Special types of matrices. Orthogonal reduction to diagonal form. Quadratic forms and reductions. Lambda matrices and related topics. Cayley-Hamilton theorem and reduced characteristic function. Canonical forms of a matrix and applications — systems of differential equations, stability criteria, matrix equations. PREREQUISITE: MA 2121 or equivalent.

MA 3046 LINEAR ALGEBRA (3-0). Special types of matrices. Orthogonal reduction of a real symmetric matrix to diagonal form. Quadratic forms and reductions to expressions involving only squares of the variables. Applications to maxima and minima. Lambda matrices and related topics. Cayley-Hamilton theorem. PREREQUISITE: MA 2045.

MA 3047 LINEAR ALGEBRA (3-0). Reduced characteristic function. Canonical forms. Idempotent and nilpotent matrices. Solutions to matrix polynomial equations. Functions of a square matrix. Applications such as to differential equations, stability criteria. PREREQUISITE: MA 3046

MA 3130 DIFFERENTIAL EQUATIONS (4-0). Review of linear ordinary differential equations. Separation of variables for partial differential equations. Fourier Series and orthogonal functions. Series solutions and special functions. Boundary value problems in two and three dimensions. PREREQUISITES: MA 1100, MA 2047 and ordinary differential equations.

MA 3132 PARTIAL DIFFERENTIAL EQUATIONS AND INTEGRAL TRANSFORMS (4-0). Solution of boundary value problems by separation of variables; Sturm-Liouville problems; Fourier, Bessel and Legendre series solutions, Laplace and Fourier transforms; classification of second order equations; applications. PREREQUISITE: MA 2121 or equivalent.

MA 3173 COMPLEX VARIABLES AND LAPLACE TRANSFORMS (4-0). Continuation of MA 3130. Complex variables, contour integration, residue theory, conformal mapping; applications to ordinary and partial differential equations including Laplace transforms and their complex inversion. PREREQUISITE: MA 3130.

MA 3181 VECTOR ANALYSIS (3-0). Vector differential and integral calculus in rectangular and orthogonal curvilinear coordinate systems; applications in various fields of engineering. PREREQUISITE: MA 1100 or equivalent.

MA 3185 TENSOR ANALYSIS (3-0). Definition of a tensor. Algebra of tensors. The metric tensor. The geometric representation of vectors in general coordinates. The co-variant derivative and its application to geodesics. The Riemann tensor, parallelism, and curvature of space. PREREQUISITE: Consent of Instructor.

MA 3232 NUMERICAL ANALYSIS (4-0). Solution of equations. Zeros of polynomials. Interpolation and approximation. Numerical differentiation and quadrature. Matrix manipulations; linear simultaneous algebraic equations. Numerical solutions of ordinary differential equations. PREREQUISITE: MA 2121 and FORTRAN programming or equivalent.

MA 3243 NUMERICAL METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS (4-1). Finite difference approximations for derivatives. Truncation and discretization errors. Parabolic and hyperbolic equations. Explicit and implicit methods. The Crank-Nicolson method. The implicit alternating direction method. Approximations at irregular boundaries. Elliptic equations. The Liebmann method. Systems of partial differential equations. Students are expected to write FORTRAN programs for the above methods. A term project involving the solution of a suitably difficult boundary value problem is required. PREREQUISITES: MA 2232 and MA 3132 or equivalent.

MA 3362 ORBITAL MECHANICS (3-0). Review of kinematics, Lagrange's equation of motion. The earth's gravitational field. Central force motion. The two body problem. The determination of orbits. The three body problem. Perturbations. PRE-REQUISITE: A course in dynamics.

MA 3565 MODERN ALGEBRA I (3-0). Elements of set theory, equivalence relations and sets. Mappings and composition of mappings. Some elementary properties of integers, e.g., Euclidean algorithm, g.c.d., l.c.m., congruence relation. Group theory, subgroups. Normal subgroups and quotient groups. Homomorphisms, isomorphisms and automorphisms. Counting principles. PREREQUISITE: Consent of Instructor.

MA 3566 MODERN ALGEBRA II (3-0). Rings, ideals and quotient rings, Euclidean rings and polynomial rings. Linear vector spaces. Fields, extension fields, Galois groups and solvability. PREREQUISITE: MA 3565.

MA 3605 FUNDAMENTALS OF ANALYSIS I (3-0). Elements of set theory, the real number system, and the usual topology in E^n. Properties of continuous functions. Differentials of vector-valued functions, Jacobians, and applications (implicit function, inverse function theorems, extremum problems). PREREQUISITE: Consent of Instructor.

MA 3606 FUNDAMENTALS OF ANALYSIS II (3-0). Functions of bounded variation and theory of Riemann-Stieltjes integration. Multiple and iterated integrals. Convergence theorems for sequences and series of functions. PREREQUISITE: MA 3605.

MA 3610 INTRODUCTION TO GENERAL TOPOLOGY (3-0). Topologies, bases and subbases, compactness and connectivity. Moore-Smith convergence theorems. Metrization and embedding theorems, uniform structures. Tychonoff product theorem, Alexandroff and Stone-Cech compactification. PREREQUISITE: MA 3605.

MA 3660 BOUNDARY VALUE PROBLEMS (3-0). The partial differential equations of physics and their solutions by separation of variables. Orthogonal sets of functions; Fourier series, their convergence and other properties. Applications to boundary value problems, verification and uniqueness of solutions. Continuation to include Bessel functions and Legendre polynomials. PREREQUISITE: MA 2121 or equivalent.

MA 3675 THEORY OF FUNCTIONS OF A COMPLEX VARIABLE I (3-0). Selected topics from the theory of functions of a real variable. Complex functions and analytic functions. Integration in the complex plane. Series of complex functions. Power series. Laurent series. PREREQUISITE: Consent of Instructor.

MA 3676 THEORY OF FUNCTIONS OF A COMPLEX VARIABLE II (3-0). Singularities of complex functions. Residues and contour integration. Zeros of analytic functions, factors of and infinite product representations for analytic functions. Maximum modulus theorems for analytic and harmonic functions. Conformal mapping. PREREQUISITE: MA 3675.

MA 3730 THEORY OF NUMERICAL COMPUTATION (3-0). Analysis of computational methods used for the solution of problems from the areas of algebraic equations, polynomial approximation, numerical differentiation and integration, and numerical solution of ordinary differential equations. PREREQUISITE: Consent of Instructor.

Graduate Courses

MA 4237 ADVANCED TOPICS IN NUMERICAL ANALYSIS (4-0). The subject matter will vary according to the abilities and interests of those enrolled. PREREQUISITE: MA 3243.

MA 4375 MATHEMATICS OF CONTINUA (4-0). Stress and strain analysis. Constitutive relations. Field equations of elastodynamics, thermodynamics, and hydrodynamics. Wave propagation and diffusion in layered media. Reflection and transmission at boundaries between dissimilar materials. Media with continuously varying characteristics. PREREQUISITE: MA 3173 or consent of Instructor.

MA 4393 TOPICS IN APPLIED MATHEMATICS (3-0). A selection of topics in applied mathematics. The course content varies. Credit may be granted for taking this course more than once. PREREQUISITE: Consent of Instructor.

MA 4501 TOPICS IN FOUNDATIONS OF MATHEMATICS (3-0). A selection of topics in foundations of mathematics. Content of the course varies. Students will be allowed credit for taking the course more than once. PREREQUISITE: Consent of Instructor.

MA 4593 TOPICS IN ALGEBRA (3-0). A selection of topics in algebra. Content of the course varies. Students will be allowed credit for taking the course more than once. PREREQUISITE: Consent of Instructor.

MA 4610 TOPOLOGY OF DYNAMICAL SYSTEMS (3-0). Dynamical systems, trajectories, limiting sets, recursive concepts, dispersive concepts, stability theory. PREREQUISITES: MA 2121 and either MA 3605 or MA 3610.

MA 4611 CALCULUS OF VARIATIONS (3-0). Bliss differential methods, Euler equations, Weierstrass-maximum principle, Legendre conditions. Perturbation techniques, numerical procedures for determining solutions, and applications to engineering and control problems. PREREQUISITE MA 2121 (programming experience desirable).

MA 4620 THEORY OF ORDINARY DIFFERENTIAL EQUATIONS (3-0). Introduction to the modern theory of ordinary differential equations. Systems of equations. Theoretical and constructive methods of solutions. PREREQUISITE: Consent of Instructor.

MA 4622 PRINCIPLES AND TECHNIQUES OF APPLIED MATHEMATICS I (3-0). Linear operators, generalized functions and Hilbert spaces. Solutions of partial differential equations by eigenfunctions. Variational techniques and their applications to eigenfunctions. Classification of partial differential equations. PREREQUISITE: MA 3132 or equivalent and MA 2172 or equivalent.

MA 4623 PRINCIPLES AND TECHNIQUES OF APPLIED MATHEMATICS II (3-0). Continuation of MA 4622. Green's functions. Integral equations, Laplace, Fourier and other transforms, including their inversion in the complex plane as applied to partial differential equations. Method of characteristics for hyperbolic equations. PREREQUISITE: MA 4622.

MA 4635 FUNCTIONS OF REAL VARIABLES I (3-0). Axiomatic set theory, development of the real numbers, semicontinuous functions, absolutely continuous functions, functions of bounded variation. Classical Lebesgue measure and integration theory in E, convergence theorems and Lp spaces. PREREQUISITE: MA 3606.

MA 4636 FUNCTIONS OF REAL VARIABLES II (3-0). Abstract measure and integration theory, signed measures, Radon-Nikodym theorem. Lebesgue decomposition and product measures. Daniell integrals and integral representation of linear functionals. PREREQUISITE: MA 4635.

MA 4637 INTRODUCTION TO FUNCTIONAL ANALYSIS (3-0). An introduction to Banach and Hilbert spaces, including open mapping-closed graph theorem, weak and weak* topologies, spectral theorems for compact Hermitian operators. Hermitian bounded and normal bounded operators. PREREQUISITE: MA 4636.

MA 4672 INTEGRAL TRANSFORMS (3-0). The Laplace, Fourier and Hankel transforms and their inversions. Applications to problems in engineering and physics. PREREQUISITE: MA 2172.

MA 4693 TOPICS IN ANALYSIS (3-0). A selection of topics in analysis. Content of the course varies. Students will be allowed credit for taking the course more than once. PREREQUISITE: Consent of Instructor.

MA 4872 TOPICS IN CALCULUS OF VARIATIONS (3-0). Recent developments in the numerical solution of problems in the calculus of variations. Foundations of numerical methods, applied to control problems. Differentials, perturbations, variational equations, adjoint system, conditions for optimum. Euler equations, maximum principle of Weierstrass and Pontryagin, the Legendre condition. Methods of solution: spectral variations, variation of extremals, dynamic programming. Applications in ship routing and missile control. PREREQUISITES: MA 2121, MA 3046 and computer programming or Consent of Instructor.

MA 4945 PROBLEM SEMINAR (3-0). Under the guidance of several faculty members, the student is exposed to a variety of problems from diverse fields with the purpose of enhancing problem-solving ability and breadth of conceptualization. The problems fall into five or six classes, each representing a central theme of a mathematical topic or problem-solving technique. Approximately half the time is devoted to lectures by the participating faculty, during which time problems are posed and relevant techniques for their solution discussed. The other half is devoted to the presentation and discussion of solutions by the students. PREREQUISITES: B.S. in Mathematics, or equivalent.

PROBABILITY AND STATISTICS

Upper Division Courses

PS 2000 ELEMENTARY PROBABILITY AND STATISTICS (4-0). A pre-calculus treatment of selected topics in probability and statistics. Includes elementary probability, binomial distribution, normal distribution, random sampling, testing hypotheses, confidence limits, regression and correlation. PREREQUISITE: College algebra.

*OA 2301 PROBABILITY (4-0).

PS 2315 DATA REDUCTION AND ERROR ANALYSIS (4-0). An introduction to the practical techniques and procedures of experiment design, data acquisition and reduction, and error analysis in the physical sciences and engineering. Topics will include systematic and random errors, distributions, estimates of distribution parameters, least-squares fitting, multiple regression, tests of goodness-of-fit, and computer techniques for the treatment of data. PREREQUISITES: CS 0110 or equivalent, MA 1100 and MA 2045.

PS 2501 INTRODUCTION TO PROBABILITY AND STATISTICS (4-0). A treatment of selected topics from probability and statistics using elementary concepts from calculus. Includes the definition of probability, useful probability distributions, sampling theory. PREREQUISITE: Integral and differential calculus, MA 1115, MA 1120 or equivalent.

Upper Division or Graduate Courses

PS 3000 MANAGEMENT STATISTICS (5-0). A one-quarter pre-calculus course in probability and statistics designed for application in management. Includes definition and interpretation of probability, random variables, expectation, important probability distributions, sampling estimation, testing hypotheses, regression.

PS 3011 PROBABILITY AND STATISTICS FOR MANAGEMENT I (4-0). A treatment of selected topics in probability and statistics for management applications using elementary concepts from calculus. Includes probability models, discrete and continuous random variables, some important distributions, sampling theory and an introduction to statistical inference.

PS 3012 PROBABILITY AND STATISTICS FOR MANAGEMENT II (4-0). A continuation of PS 3011. Includes inference for normal populations, estimation procedures, non-parametric procedures and linear models. PREREQUISITE: PS 3011 or consent of Instructor.

*OA 3302 PROBABILITY AND STATISTICS (4-1).

*OA 3303 STATISTICS (4-1).

PS 3401 INTERMEDIATE PROBABILITY AND STATISTICS I (4-0). A course in probability using the tools of calculus and leading toward applications in mathematical statistics. Includes topics from set theory, definition and calculation of probability, random variables and distribution functions, some standard distributions, joint distributions. PREREQUISITE: MA 1100 or equivalent.

PS 3402 INTERMEDIATE PROBABILITY AND STATISTICS II (4-0). A continuation of PS 3401 covering topics from mathematical statistics. Includes topics from sampling and statistics, estimation and testing hypotheses, Bayesian methods, and least squares regression theory. PREREQUISITE: PS 3401 or consent of Instructor.

PS 3411 APPLIED PROBABILITY THEORY I (4-1). Axiomatic probability, random variables, distribution functions, transformation of random variables, limiting distribution, stationary and ergodic processes. PREREQUISITE: MA 2121.

PS 3412 APPLIED PROBABILITY THEORY II (4-0). Stochastic processes, time series, linear mean-square estimation. Brownian motion and Markov processes and Poisson processes PREREQUISITE: PS 3411 or consent of Instructor.

PS 3421 NONPARAMETRIC STATISTICS (4-0). One-sample tests, two-sample tests, tests for independence, nonparametric analysis of variance and correlation statistics. PREREQUISITE: Consent of Instructor.

PS 3441 ANALYSIS OF VARIANCE AND DESIGN OF EXPERIMENTS (4-0). Linear models, noise-reducing designs, fixed random and mixed models and incomplete designs. PREREQUISITE: Consent of Instructor.

PS 3510 SELECTED TOPICS IN PROBABILITY AND STATICS (2-0 to 5-0). Topics will be selected by instructor to fit the needs and background of the students. The topics may include advanced probability, sampling inspection, quality assurance, nonparametric methods, and sequential analysis. The course may be repeated for credit if the topic changes. PREREQUISITE: PS 3303 or consent of the instructor.

*OA 3510 SELECTED TOPICS IN PROBABILITY AND STATISTICS (2-0 to 5-0).

Graduate Courses

PS 4001 ADVANCED PROBABILITY THEORY (3-0). Axiomatic probability, random variables and their probability distributions, parameters of probability distributions, characteristic functions and limit theorems. PREREQUISITE: Advanced calculus or consent of Instructor.

PS 4002 ADVANCED STATISTICS AND DECISION THEORY (3-0). Sample moments and their functions, order statistics, theory of runs, significance tests and theory of estimation. PREREQUISITE: PS 4001 or consent of Instructor.

*OA 4306 APPLIED STATISTICS (4-0).

*OA 4321 DESIGN OF EXPERIMENTS (3-1).

*OA 4322 SAMPLE INSPECTION AND QUALITY ASSURANCE (3-1).

*OA 4323 DECISION THEORY (3-0).

PS 4325 ADVANCED DESIGN OF EXPERIMENTS (4-0). Incomplete block designs. Youden squares, fractional designs, response surfaces and robustness properties of analysis of variance tests. PREREQUISITE: PS 4321.

*OA 4431 ADVANCED PROBABILITY (3-0).

*OA 4432 STOCHASTIC PROCESSES I (4-0).

*OA 4433 STOCHASTIC PROCESSES II (4-0).

*OA 4440 TIME SERIES ANALYSIS (4-0).

PS 4510 SELECTED TOPICS IN PROBABILITY AND STATISTICS (2-0 to 5-0). Topics will be selected by instructor to fit the needs and background of the students. The topics may include advanced probability, sampling inspection, quality assurance, nonparametric methods, and sequential analysis. The course may be repeated for credit if the topic changes. PREREQUISITE: PS 3303 or consent of the instructor.

*OA 4510 SELECTED TOPICS IN PROBABILITY AND STATISTICS (2-0 to 5-0).

**See listing under Operations Research and Administrative Sciences Department.*

DEPARTMENT OF MECHANICAL ENGINEERING

ROBERT HARRY NUNN, Associate Professor of Mechanical Engineering; Chairman (1968)*, B.S., Univ. of California at Los Angeles, 1955; M.S. M.E., 1964; Ph.D., Univ. of California at Davis, 1967.

JOHN EDISON BROCK, Professor of Mechanical Engineering (1954); B.S.M.E., Purdue Univ., 1938; M.S.E., 1941; Ph.D., Univ. of Minnesota, 1950.

JOSEPH GILLES CANTIN, Professor of Mechanical Engineering (1960); B.A.Sc., Ecole Polytechnique at Montreal, 1950; M.Sc., Stanford Univ., 1960; Ph.D., Univ. of California at Berkeley, 1968.

THOMAS EDWARD COOPER, Assistant Professor of Mechanical Engineering (1970); B.S., Univ. of California at Berkeley, 1966; M.S.M.E., 1967; Ph.D., 1970.

CLARENCE JIMMY GARRISON, Assistant Professor of Mechanical Engineering (1970); B.S.M.E., Univ. of Nebraska, 1960; M.S.M.E., 1962; Ph.D., Univ. of Washington, 1968.

THOMAS MICHAEL HOULIHAN, Associate Professor of Mechanical Engineering (1969); B.M.E., Manhattan College, 1961; Ph.D., Syracuse Univ., 1968.

MATTHEW DENNIS KELLEHER, Associate Professor of Mechanical Engineering (1967); B.S. Univ. of Notre Dame, 1961; M.S.M.E., 1963; Ph.D., 1966.

PAUL JAMES MARTO, Associate Professor of Mechanical Engineering (1965); B.S., Univ. of Notre Dame, 1960; M.S. in Nuc.Sci., Massachusetts Institute of Technology, 1962; Sc.D., 1965.

EDWIN A. MCKINNON, Assistant Professor of Mechanical Engineering (1972); B.Met.E., Univ. of Nevada, 1965; M.S.M.E., 1967; Ph.D., Univ. of Wisconsin, 1972.

ROBERT EUGENE NEWTON, Professor of Mechanical Engineering (1951); B.S.M.E., Washington Univ., 1938; M.S., 1939; Ph.D., Univ. of Michigan, 1951.

DONG HUU NGUYEN, Associate Professor of Mechanical Engineering (1969); B. S. M. E., Purdue Univ., 1960; M.S. in Nuc.Eng., 1961; Ph.D., Univ. of California at Berkeley, 1965.

ROY WALTERS PROWELL, Professor of Mechanical Engineering (1946); B.S. in I.E., Lehigh Univ., 1936; M.S.M.E., Univ. of Pittsburgh, 1943.

PAUL FRANCIS PUCCI, Professor of Mechanical Engineering (1956); B.S., Purdue Univ., 1949; M.S. M.E., 1950; Ph.D., Stanford Univ., 1955.

DAVID SALINAS, Assistant Professor of Mechanical Engineering (1970); B.S., 1959; M.H. 1962; Ph.d., Univ. of California at Los Angeles, 1968.

TURGUT SARPKAYA, Professor of Mechanical Engineering (1967); M.S.M.E., Tech. Univ. of Istanbul, 1951; Ph.D., Univ. of Iowa, 1954.

EMERITUS FACULTY

ERNEST KENNETH GATCOMBE, Professor Emeritus (1946); BS., Univ. of Maine, 1931; M.S., Purdue Univ., 1939; Ph.D., Cornell Univ., 1944.

HAROLD MARSHALL WRIGHT, Professor Emeritus (1945); B.Sc. in M.E., North Carolina State College, 1930; M.M.E., Rensselaer Polytechnic Institute, 1931.

** The year of joining the Postgraduate School Faculty is indicated in parentheses.*

DEPARTMENTAL REQUIREMENTS FOR DEGREES IN MECHANICAL ENGINEERING

A specific curriculum should be consistent with the general minimum requirements for the degree as determined by the Academic Council.

Any program leading to award of a degree must be approved by the Chairman of the Department of Mechanical Engineering at least two quarters before completion. In general, approved programs will require more than minimum degree requirements in order to conform to the needs and objectives of the United States Navy.

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

1. *Entrance Requirements.* Prior to entering an approved curriculum, a student must have successfully completed college courses as follows: mathematics through integral calculus, one year of chemistry, and one year of physics.

2. *Mechanical Engineering Courses.* A minimum of 58 quarter hours in mechanical engineering courses is required, at least 30 of them being in courses 3000-4999.

3. *Other Specific Coverage.* The following minimum requirements must be met in each of the indicated disciplines:

Mathematics — One course in each of the following subjects: linear algebra, differential equations and series, numerical methods and digital computers, and partial differential equations.

Electrical Engineering — 10 quarter hours.

Material Science — 4 quarter hours.

Some of these requirements may, with the consent of the departmental chairman, be met by transfer credit.

4. *Upper Division Credit.* Minimum credit of 94 quarter hours in upper division or higher level courses is required.

5. *Sample Program.* A sample program satisfying the above requirements is given under Naval Engineering Programs, Curriculum No. 570.

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

1. *Areas of Specialization.* The Department of Mechanical Engineering offers Master of Science degrees with specialization in the following three areas: engineering mechanics, thermo-fluid sciences, and ocean mechanical engineering.

2. *Undergraduate Preparation.* A candidate shall have satisfied the requirements for the degree of Bachelor of Science in Engineering. Credit requirement in succeeding paragraphs must be met by courses in addition to those used to satisfy this requirement.

3. *Mechanical Engineering Courses.* The Master of Science degree in Mechanical Engineering requires a minimum of 36 quarter hours of graduate level credits, at least 10 of them in courses 400-499, plus an acceptable thesis.

4. *Courses in Other Departments.* A minimum of 8 quarter hours of graduate credit must be earned outside of the Mechanical Engineering Department.

5. *Sample Program.* Various areas of specialization leading to the Master of Science degree in Mechanical Engineering are given under Naval Engineering Programs, Curriculum No. 570.

THE PROGRAM LEADING TO THE DEGREE OF MECHANICAL ENGINEER

Graduate students may, upon satisfactory completion of seven quarters of academic work, enter the program leading to the degree of Mechanical Engineer. Normally, this program is of three years' duration.

The Engineer's degree requires a minimum of 76 graduate course credits, at least 30 of them in courses 4000-4999, plus an acceptable thesis pertinent to the area of specialization among the following areas: engineering mechanics, thermo-fluid sciences, and ocean mechanical engineering. An acceptable thesis for the Engineer's degree may also be accepted as meeting the thesis requirements for the Master's degree.

An advisor will be appointed by the departmental Chairman for consultation in the development of a program of study and research. Approval of all programs must be obtained from the Chairman, Department of Mechanical Engineering.

THE PROGRAM LEADING TO THE DEGREE OF DOCTOR OF PHILOSOPHY

Graduate officer students may, upon satisfactory completion of eleven quarters of academic work, apply for the program leading to the degree of Doctor of Philosophy. Normally, this program requires the equivalent of at least three academic years of study beyond the baccalaureate level, with at least one academic year being spent at the Naval Postgraduate School. A Doctoral Committee is appointed for the student which has the full responsibility for providing a program of study suitable to the needs of the student and the requirements for award of the degree.

The Department of Mechanical Engineering is authorized to offer doctorate degrees in the areas of mechanics of deformable bodies, fluid mechanics, and heat transfer.

A dissertation advisor is appointed by the Department Chairman who, together with the Doctoral Committee, is responsible for the development of a program of study and research. Approval of the programs must be obtained from the Academic Council.

In order to provide civilian scientists and engineers of the Navy an opportunity to extend their education to the doctoral level, admission to the Ph. D. program is available to qualified applicants for the Cooperative Doctoral Program. Interested individuals should address their inquiries to the Provost of the Naval Postgraduate School.

MECHANICAL ENGINEERING LABORATORIES

The Mechanical Engineering laboratories are designed as complements to the educational mission and research interests of the department. In addition to the extensive facilities for the support of student and faculty research, a variety of general use equipment is available. This includes machinery for the investigation of dynamic and static problems in engineering mechanics; a water tunnel, a water table, and a wave channel; facilities for experimentation with air flows from incompressible through supersonic velocities; demonstration equipment for instruction in thermal transport phenomena; a laboratory for demonstrating nuclear engineering principles; and a fluid power control and fluidics laboratory. The experimentation adventure is further enhanced by a broad selection of analog and digital data acquisition and processing equipment.

MECHANICAL ENGINEERING

ME 0810 THESIS RESEARCH (0-0). Every student conducting thesis research will enroll in this course.

Upper Division Courses

ME 2101 ENGINEERING THERMODYNAMICS (4-1). A comprehensive coverage of the fundamental concepts of classical thermodynamics, with insight toward microscopic phenomena. The laws of thermodynamics. Equations of state. Thermodynamic properties of substances. Entropy, irreversibility and availability. Cycle analysis. Gas-vapor mixtures. Combustion and dissociation. PREREQUISITE: MA 1100.

ME 2120 ELEMENTS OF ENGINEERING THERMODYNAMICS (3-2). The fundamental concepts of thermodynamics, thermodynamic properties and equations of state. The first law of thermodynamics. Entropy and the second law of thermodynamics. The ideal gas. Gaseous mixtures. Cycle analysis with some applications. PREREQUISITE: PH 1015.

ME 2201 INTRODUCTION TO FLUID MECHANICS (3-2). Properties of fluids. Fluid statics, stability of submerged bodies. Mass, momentum, and energy considerations in steady flows. Dynamic similitude and dimensional analysis. Fluid measurement and control, turbo-machinery. Basic effects of fluid friction. Emphasis on naval engineering applications and problem solving. PREREQUISITE: ME 2502.

ME 2410 MECHANICAL ENGINEERING LAB I (2-3). Fundamentals of mechanical measurement systems, structured laboratory experiments using resistance strain gages, pressure transducers, temperature, flow and velocity measurement devices. PREREQUISITES: ME 2101, ME 2201, ME 2502, and ME 2610, any of which may be taken concurrently.

ME 2502 DYNAMICS (4-0). Kinematics and kinetics of a particle. Work and energy. Impulse and momentum. Plane motion of a rigid body. PREREQUISITE: ME 2610 or ME 2561 or equivalent.

ME 2561 STATICS (3-0). This course, designed specifically for the B.S. in Engineering Science Curriculum, deals with

forces and force systems, moments and couples, resultants, equilibrants, free body diagrams, equilibrium, simple structures, friction, first and second moments, and centroids. PREREQUISITE: MA 1106.

ME 2562 DYNAMICS (4-0). This course, designed specifically for the B.S. in Engineering Science Curriculum, deals with basic concepts of kinematics, Newton's laws, d'Alembert's principle, work and energy, impulse and momentum, plane motion of a rigid body. PREREQUISITE: ME 2561.

ME 2610 MECHANICS OF SOLIDS I (5-2). This course combines the fundamentals of statics and a first course in mechanics of solids. Topics include laws of equilibrium in vector form, applications to structures and machines, centroids and second moments, shear and bending moment diagrams, uniaxial and biaxial stresses and deformations, torsion of circular members, shear and bending stresses in beams, beam deflections, simple statically indeterminate problems. Supporting laboratory experiments in mechanics of solids. PREREQUISITE: MA 1100 (may be taken concurrently).

Upper Division or Graduate Courses

ME 3150 HEAT TRANSFER (4-2). Elementary treatment of the principles of Heat Transfer applicable to problems in Mechanical Engineering. Steady and unsteady conduction. Principles of forced and natural convection. Thermal radiation. Boiling. Condensation. Heat exchanger analysis. Use of the thermal circuit, analog, numerical and graphical techniques. Selected laboratory experiments. PREREQUISITES: ME 2101, ME 2201, MA 3132 (may be taken concurrently).

ME 3201 PRINCIPLES OF FLUID DYNAMICS (3-1). An introduction to the methods for analysis of ideal and viscous fluid flows. Concepts of steady fluid motion and dynamics in three dimensions. Motion of a deformable body. Simple irrotational flows. Vortex dynamics. Momentum and moment of momentum. Compressibility effects and one-dimensional compressible flows. Gravity flows. Fundamentals of viscous fluid flows. PREREQUISITES: MA 3132 (may be taken concurrently), ME 2201.

ME 3202 GAS DYNAMICS (3-1). The effects of compressibility and the basic equations governing compressible flows. Wave propagation in compressible media. One-dimensional adiabatic flows. Rayleigh flows. Prandtl-Meyer flow. Normal and oblique shock waves. Current Mechanical Engineering applications, devices, and systems. PREREQUISITES: ME 2101 and ME 2201.

ME 3301 NUCLEAR POWER SYSTEMS (5-0). Atomic and nuclear structures. Nuclear reactions; fission and fusion. Neutron interactions with matter: cross section, slowing-down and diffusion of neutrons. Fundamentals of nuclear reactor analysis: neutronic and thermal aspects in core design. Principal reactor types. Biological radiation protection. Applications of radioisotopes. PREREQUISITES: ME 3150 (may be taken concurrently) or equivalent.

ME 3315 NUCLEAR MEASUREMENTS LAB (1-4). Principles of radiation detection. The use of various health physics instruments and radiation detectors; gas-filled, scintillation, crystal and foil detectors; calibration of detectors. Experiments in neutron physics: determination of neutron Fermi age and diffusion length. Neutron fast and thermal fluxes mapping by various detectors. Determination of flux perturbation by local absorption. Gamma ray spectrometry: pulse height analyzer. PREREQUISITES: ME 2410, ME 3301 or equivalent.

ME 3341 RADIATION SHIELDING (4-0). Biological hazards of nuclear radiations. Interaction of electromagnetic radiation, charged particles, and neutrons with matter. Shielding of reactors and radioactive materials. Miscellaneous topics in shielding: effects of ducts and voids in shields, heating with shields, beam traps, shielding windows. PREREQUISITES: ME 3301 or equivalent.

ME 3430 MECHANICAL ENGINEERING LAB II (1-3). A project-oriented continuation of mechanical measurement systems, with emphasis upon the use of sound engineering practices in the conduct and documentation of an independent experimental investigation. Application of measurement techniques using group projects in thermodynamics, mechanics of solids, heat transfer, fluid flow, vibrations and nuclear radiation detection. PREREQUISITES: ME 2410, ME 3150, ME 3521, and ME 3611.

ME 3440 ENGINEERING SYSTEMS ANALYSIS (4-0). Classification of engineering problems. Study of equilibrium, eigenvalue and propagation problems for both discrete and continuous systems. Rigorous construction of mathematical models. Classical methods of solution and numerical techniques. Digital computer applications. Problems in the theory of plates and shells, heat transfer, hydromechanics, and other areas of Mechanical Engineering are used as illustrations throughout the course. PREREQUISITES: ME 2101, ME 2201, ME 3521, and ME 3611.

ME 3450 THERMODYNAMICS OF MARINE POWER SYSTEMS (3-2). Current applications of thermodynamic principles to Marine Power Systems. Detailed analysis of vapor and gas power cycles. The characteristics of engines, compressors, and turbines. Refrigeration, air conditioning and cryogenic systems. Direct energy conversion. Selected laboratory experiments. PREREQUISITE: ME 3150.

ME 3500 MECHANICAL VIBRATIONS AND NOISE CONTROL (4-0). Free and forced vibrations of discrete and continuous linear systems. Damping mechanisms, including complex modulus description of materials. Mechanical impedance. Transfer matrices. Case studies of shipboard vibration and noise problems. PREREQUISITE: MA 2232 or equivalent, PH 3157, and PH 3451.

ME 3521 MECHANICAL VIBRATIONS (3-2). Kinematics and kinetics of free and forced vibration of discrete linear systems. Applications to vibration isolation and suppression in mechanical systems. Vibration of bars, shafts and beams. Numerical solutions. Laboratory experiments with mechanical and simulated systems. PREREQUISITES: ME 2502, ME 2610, MA 2232, and MA 3132 (may be taken concurrently).

ME 3611 MECHANICS OF SOLIDS II (4-0). Constitutive laws for linear elastic solids. Fundamentals of the theory of elasticity. Applications to beams. Stability of simple structures. Torsion of members with non-circular cross section. Elements of plate and shell behavior. PREREQUISITES: ME 2502, ME 2601, MA 2121, and MA 2232.

ME 3711 DESIGN OF MACHINE ELEMENTS (3-2). The design of screw fastenings, springs, shafts, bearings, gears, flexible power-transmitting elements, brakes and clutches are studied with consideration being given to materials, tolerances, variable loads, stress concentration and theories of failure. PREREQUISITE: ME 3611.

ME 3712 DESIGN OF MACHINERY (2-4). Static, kinematic and dynamic analysis and design of cams, gears and linkages. Projects involving conceptual design of complete machines. Consideration is given to manufacturing and machining methods. PREREQUISITES: ME 3711 and ME 3521.

ME 3801 FLUID POWER CONTROL (3-2). Fluids as power transmission media. Operation and analysis of control valves and actuators. Hydraulic power elements. Steady state and dynamic performance of electro-hydraulic servovalves and servomechanisms. Design criteria for fluid power controls. In-

troduction of pneumatic systems. Some time-dependent flow problems. Introduction to fluidics. PREREQUISITES: ME 3201 (may be taken concurrently).

Graduate Courses

ME 4140 DIRECT ENERGY CONVERSION (3-0). The principles of direct energy conversion employing thermoelectric, thermionic, photo voltaic, magneto-hydrodynamic, and fuel cell power generators. PREREQUISITES: ME 3150, ME 3202, EE 2101, and MA 2121.

ME 4161 CONDUCTION AND RADIATION HEAT TRANSFER (4-0). Steady-state heat conduction in multi-dimensions with and without heat sources. Transient conduction. Numerical methods for heat conduction. Variational methods. Mechanical Engineering applications. Black body radiation; radiation from real surfaces; radiation exchange between finite surfaces. The network method, radiation through participating media. Conjugate conduction and radiation problems. PREREQUISITES: ME 3150.

ME 4162 CONVECTION HEAT TRANSFER (4-0). Fundamental principles of forced and free convection. Dimensionless correlations. Heat transfer during phase changes. Combined conduction, convection and radiation heat transfer systems. Heat exchanger analysis with Mechanical Engineering applications. PREREQUISITES: ME 4161, ME 4220 (may be taken concurrently).

ME 4211 HYDRODYNAMICS (4-0). Kinematics and dynamics of inviscid fluid flow. Vorticity, circulation, velocity potential and stream function. Solutions to flow about two- and three-dimensional bodies. Simple unsteady flows — virtual mass. Conformal transformations, hydrofoils, approximate methods. Introduction to free streamline flows and fluid wave motions with naval engineering applications. PREREQUISITE: ME 3201.

ME 4220 VISCOUS FLOW (4-0). Development of continuity and Navier-Stokes equations. Exact solutions of steady and unsteady viscous flow problems. Low Reynolds number flows. Development of the boundary layer equations. Similarity variables, numerical and integral techniques. Separation, boundary layer control, compressibility effects. Time-dependent boundary layers. Stability, transition, and turbulence. Nature of turbulence, phenomenological theories, calculation of turbulent flows. PREREQUISITE: ME 4211 (may be taken concurrently).

ME 4230 ADVANCED TOPICS IN FLUID DYNAMICS AND HEAT TRANSFER (4-0). Topics selected in accordance with the research interests of students and staff. Advanced analytical methods. Surveys of current Mechanical Engineering technologies. Extensions to the theories of fluid flow and heat transfer. PREREQUISITES: ME 4161, ME 4211, ME 4220, and MA 2172 (may be taken concurrently), or consent of Instructor.

ME 4240 ADVANCED HYDRODYNAMICS (4-0) Topics selected in accordance with the current research interests of students and staff. Jets, wakes, cavities; free-streamline theory. Steady and unsteady separated flows. Analysis of rotating fluid masses. Wave propagation in complex systems. PREREQUISITES: ME 4211, MA 3173 (may be taken concurrently), or consent of Instructor.

ME 4311 NUCLEAR REACTOR ANALYSIS I (4-0). Review of neutron interactions with matter. Neutron cross sections; resonance phenomena and Doppler effect. The fission process. The slowing-down of neutrons in media with and without absorption. The diffusion of neutrons. Space-dependent slowing down of neutrons: Fermi Age Theory. Low-energy neutrons and thermal reactors. Criticality of homogeneous reactors. PREREQUISITES: ME 3301 or equivalent and MA 3132.

ME 4312 NUCLEAR REACTOR ANALYSIS II (4-0). Design parameters in heterogeneous reactors. Reflected reactors. Multigroup diffusion methods. Reactor kinetics and control: the effect of delayed neutrons; step and ram change in reactivity. Reactor properties over life: temperature coefficients of reactivity; fission product poisoning; burn-up and conversion. Application of perturbation theory in the analysis of reactivity change. PREREQUISITE: ME 4311.

ME 4321 REACTOR ENGINEERING PRINCIPLES AND DESIGN (4-2). Reactor heat generation and removal. Thermal stress analysis. Nuclear Fuel Cell. Change in reactivity during core lifetime. Overriding of fission product poisoning. Principal types of reactor systems. The synthesis of reactor physics, heat transfer and hydraulics, properties of materials and safety requirements in reactor design. Student group design project. PREREQUISITES: ME 4312, ME 3450 (may be taken concurrently).

ME 4512 ADVANCED DYNAMICS (4-0). Three-dimensional kinematics of particles and rigid bodies. The inertia tensor. Dyadic-vector formulation of dynamical equations. Lagrangian methods. Topics of special interest such as Hamiltonian methods, space dynamics, electromechanical systems. PREREQUISITE: ME 3521.

ME 4522 ADVANCED VIBRATIONS (4-0). Matrix analysis of mechanical systems with many degrees of freedom. Transient response. Shock isolation. Non-linear systems. Digital computer solutions. PREREQUISITE: ME 3521.

ME 4612 ADVANCED MECHANICS OF SOLIDS (4-0). Stress tensor and theories of inelastic action. Selected applications of the theory of elasticity. Topics of special interest, such as instability of simple framed structures, matrix methods of structural analysis, analysis of pressure vessels, thermal stresses. PREREQUISITES: MA 3132 and ME 3611.

ME 4613 FINITE ELEMENT METHODS (4-0). Systematic construction of line, surface, and volume elements for one, two and three dimensional problems of elasticity. Applications to trusses, frames, plane stress and plane strain problems, plates and shells, with emphasis on ship structures. Extensions to vibrations, buckling, and large deformations. PREREQUISITE: ME 3611.

ME 4620 THEORY OF CONTINUOUS MEDIA (4-0). Tensor analysis. Stress and strain tensors. Motion of a continuum. Energy and entropy. Constitutive equations. Mechanical applications in the theory of elasticity and fluid dynamics. PREREQUISITES: ME 2201, ME 3611, and MA 3132.

ME 4902 ADVANCED STUDY IN MECHANICAL ENGINEERING (2-0 to 6-0). Directed advanced study in mechanical engineering on a subject of mutual interest to student and staff member. May be repeated for credit with a different topic. PREREQUISITE: Permission of Department Chairman.

DEPARTMENT OF METEOROLOGY

George Joseph Haltiner, Distinguished Professor and Professor of Meteorology; Chairman (1946)*; B.S., College of St. Thomas, 1940; Ph.D., University of Wisconsin, 1942; Ph.D., 1948.

Ronnie Lee Alberty, Assistant Professor of Meteorology (1967); B.S., University of Missouri (Columbia Campus), 1963; M.S., 1965; Ph.D., 1967.

Kenneth LaVern Davidson, Assistant Professor of Meteorology (1970); B.S., University of Minnesota, 1962; M.S., University of Michigan, 1966; Ph.D., 1970.

Russell Leonard Elsberry, Associate Professor of Meteorology (1968); B.S., Colorado State University, 1963; Ph.D., 1968.

William Lawrence Gates, Professor of Meteorology and Oceanography (1972); B.S., Massachusetts Institute of Technology, 1950; S.M., 1951; Ss.D., 1955.

Harry Dean Hamilton, Commander, U. S. Navy; Assistant Professor of Meteorology (1969); B.S., University of Texas, 1955; M.S., Naval Postgraduate School, 1961; Fil. Lic. University of Stockholm (Sweden), 1970.

Robert Lee Haney, Assistant Professor of Meteorology (1970); A.B., George Washington University 1964; Ph.D., University of California at Los Angeles, 1971.

Frank Lionel Martin, Professor of Meteorology (1947); B.A., University of British Columbia, 1936; M.A., 1938; Ph.D., University of Chicago, 1941.

Winslow Blodgett Oakes, Lieutenant Commander, U. S. Navy; Instructor in Meteorology (1968); B.S., Rensselaer Polytechnic Institute, 1955; M.S., Naval Postgraduate School, 1962.

Robert Joseph Renard, Professor of Meteorology (1952); M.S., University of Chicago, 1952; Ph.D., Florida State University, 1970.

Delvin Leroy Schardt, Lieutenant Commander, U. S. Navy; Instructor in Meteorology (1970); B.A., Duane College, 1961; M.S., Naval Postgraduate School, 1966.

Charles Luther Taylor, Associate Professor of Meteorology (1954); B.S., Pennsylvania State University, 1942; M.S., 1947.

Martin Stephen Tracton, Assistant Professor of Meteorology (1972); B.S., University of Massachusetts, 1966; M.S., Massachusetts Institute of Technology, 1969; Ph.D., 1972.

Willem Van Der Bijl, Associate Professor of Meteorology (1961); B.Sc., Free University of Amsterdam, 1941; M.Sc., 1943; Ph.D., State University, Utrecht, 1952.

Roger Terry Williams, Associate Professor of Meteorology, (1968); A.B., University of California at Los Angeles, 1959; M.A., 1961; Ph.D., 1963.

EMERITUS FACULTY

William Dwight Duthie, Distinguished Professor Emeritus (1945); B.A., University of Washington, 1935; M.S., 1937; Ph.D., Princeton University, 1940.

** The year of joining the Postgraduate School Faculty is indicated in parentheses.*

METEOROLOGY LABORATORIES

Meteorology facilities include all instruments in present-day use for measuring the physical and dynamic state of the atmosphere, as well as radio teletype and facsimile communications equipment for the rapid reception and dissemination of weather data in coded and analysed form for the entire northern hemisphere.

The instruments for gathering weather data include rawinsonde equipment, which provides a continuous recording of temperature, pressure, humidity and wind direction and velocities at designated levels above the surface; radiosonde equipment whereby pressure, temperature and humidity information is transmitted to ground via radio signals from heights that may extend above 100,000 feet; a wiresonde that measures air temperature and humidity conditions in the lower strata of the atmosphere, and inversion meter designed for remote recordings of free air temperature at designated heights in the boundary layer.

The school has in daily operation an automatic picture transmission (APT) receiving apparatus for the reception of pictures from the NIMBUS, ESSA, and ATS weather satellites. Rectification grid templates are used in the laboratories for direct correlation of current satellite pictures with conventional synoptic analyses and nephanalyses.

Four meteorological laboratories are served by a closed circuit television network which has the transmitting studio in close proximity. Some of the equipment in the studio includes TV camera, slide and movie projectors, sound facilities, and a video tape recorder.

The proximity of the Fleet Numerical Weather Central on the school grounds provides introduction to the latest environmental computer products and the high speed data links utilized to provide transmission and automatic reproduction through a world-wide network. In addition, the Navy research facility known as the Environmental Prediction Research Facility (EPRF) has been established in in the local area and will aid the NPS programs in meteorological and oceanographic research.

DEPARTMENTAL REQUIREMENTS FOR DEGREES IN METEOROLOGY

BACHELOR OF SCIENCE IN METEOROLOGY

1. The degree of Bachelor of Science in Meteorology requires completion of:

   a. Mathematics courses including differential and integral calculus, vectors, digital computers, and numerical methods.

b. Thirty-six quarter hours of meteorology courses including the basic sequences in dynamic, physical and synoptic metorology.

c. An acceptable research paper.

MASTER OF SCIENCE IN METEOROLOGY

1. Entrance to a program leading to a Master of Science degree in Meteorology requires mathematics through differential and integral calculus and a minimum of one year of college physics.

2. The degree of Master of Science in Meteorology requires completion of:

a. Mathematics courses in vector analysis, partial differential equations, and application of numerical methods and computers to the solution of partial differential equations.

b. Thirty-five quarter hours of graduate meteorology courses of which 18 hours must be in the 4000 series.

c. The basic sequence of graduate courses in the fields of dynamical, physical and synoptic meteorology, must be included in these 35 hours.

d. An acceptable thesis.

DOCTOR OF PHILOSOPHY

The Ph. D. is offered in the Department of Meteorology in the following areas of study: numerical weather prediction, geophysical fluid dynamics, analysis of atmospheric systems, and tropical meteorology.

The requirements for the degree are grouped into three categories: course work, research in conjunction with an approved dissertation, examination in both the major and a minor field, and languages. The minor field is usually in oceanography, mathematics or physics.

The required examinations are described in this catalog in the section Requirements for the Doctor's Degree. The Department of Meteorology also requires a preliminary examination in order to show evidence of acceptability as a doctoral candidate.

Prospective students should consult with the Chairman of the Department of Meteorology for further information and guidance regarding doctoral programs.

METEOROLOGY

MR 0110 FACULTY SEMINAR (1-0). An introduction to the faculty. Purpose is to hear descriptions of research and teaching interests of the members of both faculties (Meteorology and Oceanography) as an orientation and as a first opportunity for exposure to possible thesis research areas. Presentations by individual faculty members. PREREQUISITE: Enrollment in Environmental Sciences Curricula.

MR 0810 THESIS RESEARCH (0-0). Every student conducting thesis research will enroll in this course.

Upper Division Courses

MR 2100 SURVEY OF METEOROLOGY (3-0). A descriptive course which treats the composition and vertical structure of the atmosphere, physical processes, general circulation, air masses, fronts, cyclones, anti-cyclones, and tropical disturbances. TEXT: Miller and Thompson, *Elements of Meteorology.* PREREQUISITE: None.

MR 2200 INTRODUCTION TO METEOROLOGY (4-0). A general course which introduces basic instruments, the physical laws governing atmospheric processes, the composition and vertical structure of the atmosphere, physical processes, cyclones and anti-cyclones, air masses, fronts, tropical disturbances, general circulation and observations from satellites. TEXT: McIntosh and Thom, *Essentials of Meteorology.* PREREQUISITES: Differential and integral calculus, PH 1011 or equivalent, or departmental approval.

MR 2205 INTRODUCTION TO METEOROLOGICAL ANALYSIS (0-4). A laboratory course in meteorological and oceanographical observations and codes; and, an introduction to the vertical structure of the troposphere and basic analysis of meteorological parameters. 500mb analysis is used to emphasize the importance of time continuity, gradients and the geostrophic wind; surface analysis focuses on the additional problems associated with frontal phenomena; graphical arithmetic techniques are practiced. TEXTS: AMS Glossary of Meteorology; departmental notes; and various NOAA, NWS and AWS Technical Publications. PREREQUISITE: MR 2200 concurrently.

MR 2420 PRINCIPLES OF MEASUREMENT (3-2). The application of the basic principles of mechanics, heat, electricity, sound and optics to meteorological instrumentation employed by the Navy with special emphasis on upper air and satellite developments. Design and operation of oceanographic instruments; recording of oceanographic observations. TEXTS: Middleton and Spilhaus, *Meteorological Instruments*; H. O. 607; departmental notes. PREREQUISITE: MA 2121.

MR 2520 CLIMATOLOGY AND STATISTICS (3-0). Discussion of climatic controls, climatic classifications and hypotheses about climatic changes. Preview of the climates of certain areas of the world which are important to the Navy. Many basic statistical quantities (mean, standard deviation, correlation and regression) will be introduced and their role in climatology demonstrated. TEXTS: Hauritz and Austin, *Climatology;* Conrad and Pollock, *Methods in Climatology;* Spiegel, *Statistics;* departmental notes. PREREQUISITE: MR 2200.

Upper Division or Graduate Courses

MR 3220 METEOROLOGICAL ANALYSIS (3-0). Techniques of evaluation, analysis and interpretation of tropospheric pressure, wind and temperature data, including an introduction to interpretation of weather satellite observations. Synoptic models of extratropical vortices, waves and frontal systems, with emphasis on three-dimensional space and time continuity of the lower troposphere. Introduction to space and time cross-sections and streamline and isotach analysis. TEXTS: Departmental notes; and various NOAA, NWS, and AWS technical publications. PREREQUISITES: MR 2200 and MR 3420; MR 4321 concurrently.

MR 3225 METEOROLOGICAL ANALYSIS LABORATORY (0-6). Laboratory course with emphasis on analysis of vertical consistency between the surface and 500mb levels; introduction to analysis at 850 and 300mb; use of weather satellite observations in analysis; practice in local weather briefing. TEXTS: Same as MR 3220. PREREQUISITE: MR 3220 concurrently.

MR 3230 TROPOSPHERIC AND STRATOSPHERIC METEOROLOGY (4-0). Observation, computation, analysis, and synoptic interpretation of tropospheric and stratospheric data (to 10mb) with emphasis on the middle and high altitude aspects of satellite meteorology, jet streams, tropopauses, vertical motion, hydrometeors, and related numerical products. TEXTS: Palmen

and Newton, *Atmospheric Circulation Systems;* reprints; and departmental notes. PREREQUISITES: MR 3220; MR 4322 or MR 3302 concurrently.

MR 3235 TROPOSPHERIC AND STRATOSPHERIC METEOROLOGY LABORATORY (0-9). Practice in the meso- and synoptic-scale analysis of parameters considered in MR 3230 with emphasis on objectivity, interrelationships, and application to forecast problems. TEXTS: Same as MR 3230. PREREQUISITE: MR 3225; MR 3230 concurrently.

MR 3240 WEATHER ELEMENTS (4-0). Analysis and forecasting of weather elements important to the oceanographer using numerical, statistical and subjective methods. Interpretation of numerically-derived prognoses and satellite observations for forecasting air mass weather elements. Problems of short and medium range forecasting in the marine layer of the tropical and extra-tropical regions, with emphasis on the meso-scale. TEXTS: Palmen and Newton, *Atmospheric Circulation Systems;* departmental notes; and various NOAA, NWS and AWS technical publications. PREREQUISITES: MR 3220, MR 3225, and MR 4321.

MR 3245 WEATHER ELEMENTS FORECASTING (0-6). Laboratory course taught in conjunction with MR 3240. Exercises in short- and medium-range forecasting at various space scales, with emphasis on low-level wind, temperature, moisture and air-sea temperature difference; practice in environmental briefing and marine forecasting. TEXTS: Same as MR 3240. PREREQUISITE: MR 3240.

MR 3250 TROPICAL AND SOUTHERN HEMISPHERE METEOROLOGY (3-0). The general circulation and air masses of the Southern hemisphere; climatology and synoptic models of the tropics; analysis and forecasting tropical weather systems with emphasis on cyclones and meteorological satellite observations. TEXTS: Atkinson, *Forecasters' Guide to Tropical Meteorology;* Palmen and Newton, *Atmospheric Circulation Systems* departmental notes; reprints. PREREQUISITES: MR 4322 or MR 3302, MR 3230.

MR 3255 TROPICAL AND SOUTHERN HEMISPHERE METEOROLOGY LABORATORY (0-6). Laboratory course associated with MR 3250. Contour (isobaric), streamline, and isotach analysis and forecasting with emphasis on climatology, tropical cyclones, and meteorological satellite observations. TEXTS: Same as MR 3250. PREREQUISITES: MR 3235, MR 3250 concurrently.

MR 3260 PROGNOSTIC CHARTS AND EXTENDED FORECASTING (3-0). Subjective and objective methods, both kinematical and dynamical, for constructing prognostic charts, upper-air and surface, with greater emphasis on the latter, graphical-numerical techniques; interpretation and alternation of computer-generated prognoses. Extended forecasting by weather type methods; interpretation of National Meteorological Center extended forecasts. TEXTS: George, *Weather Forecasting for Aeronautics;* Petterssen, *Weather Analysis and Forecasting Vol. I;* Environmental Science Services Administration and Fleet Numerical Weather Central Manuals; departmental notes. PREREQUISITES: MR 4323 or MR 3303 concurrently.

MR 3265 PROGNOSTIC CHARTS AND EXTENDED FORECASTING LABORATORY (0-6). Laboratory course taught in conjunction with MR 3260. Extended analysis; practice in construction and interpretation of prognostic charts. Weather typing; interpretation of National Meteorological Center extended forecasts. TEXTS: George, *Weather Forecasting for Aeronautics;* Environmental Science Services Administration and Fleet Numerical Weather Central Manuals; departmental notes. PREREQUISITES: MR 3235; MR 3260 concurrently.

MR 3279 CASE STUDIES IN ENVIRONMENTAL SUPPORT (0-4). Laboratory experience in the application of oceanographical and meteorological analysis and prediction in support of naval strategy and tactics, emphasizing the planning, execution and situation analysis of naval operations from an environmental viewpoint. TEXTS: NAV Wea Serv Com Support manual; NWS 3360/1 (C); departmental notes; NOAA, NWS and AWS publications. PREREQUISITES: OC 3616 and OC 3621 concurrently; and OC 3611, OC 3615, MR 3260 and MR 3265; or OC 4601, OC 3605, MR 3240 and MR 3245.

MR 3301 FUNDAMENTALS OF DYNAMIC METEOROLOGY I (4-0). Equations of motion; wind types; trajectories and streamlines; vertical variation of wind; friction, surface and spiral layers; continuity and tendency equations; mechanism of pressure changes, vorticity and divergence equations. TEXT: Haltiner and Martin, *Dynamical and Physical Meteorology.* PREREQUISITE: MR 3420.

MR 3302 FUNDAMENTALS OF DYNAMIC METEOROLOGY II (4-0). Simple types of wave motion, filtering; objective analysis and numerical prediction; barotropic and baroclinic models, baroclinic instability; vertical velocity; finite differencing relaxation; numerical errors. TEXT: Haltiner and Martin, *Dynamical and Physical Meteorology;* departmental notes. PREREQUISITE: MR 3301.

MR 3303 COMPUTER METEOROLOGY (4-2). Objective analysis, barotropic and baroclinic models, computation schemes including instability effects, computer products of the Fleet Numerical Weather Central. Laboratory exercises in numerical weather prediction. TEXT: Haltiner, *Numerical Weather Prediction.* PREREQUISITES: MR 3302, CS 2110.

MR 3403 INTRODUCTION TO ENERGY-TRANSFER PROCESSES (4-0). Properties of radiating matter in general; solar and terrestial radiation and their effects on temperature distribution; the head budget; structure of the wind in the friction layer and its significance in turbulent transfer; air-mass modification, forecasting the micrometeorological variables; interpretation of satellite radiation measurements from thermodynamic and heat budget considerations. TEXT: Haltiner and Martin, *Dynamical and Physical Meteorology;* departmental notes. PREREQUISITE: MR 3302.

MR 3420 GEOPHYSICAL THERMODYNAMICS (4-0). The physical variables; properties of gases, water and moist air; equations of state and the laws of thermodynamics applied to the atmosphere and oceans; entrophy adiabatic processes and potential temperatures; meteorological thermodynamic diagrams; geopotential and hydrostatic equilibrium, static instability criteria and phenomena. TEXT: Haltiner and Martin, *Dynamical and Physical Meteorology.* PREREQUISITE: MA 3132 concurrently.

MR 3421 CLOUD PHYSICS AND ATMOSPHERIC POLLUTION (3-1). Basic principles of cloud and precipitation physics and their applications to weather modification such as dispersion of warm and cold fog, convective cloud modification, suppression of hail and tornadoes, and suppression and enhancement of precipitation. Basic principles and theories of atmospheric pollution and the meteorological and ecological results of the changes in the natural atmosphere. TEXT: Byers, *Elements of Cloud Physics;* relevant journal articles; and departmental notes. PREREQUISITES: MR 3420, MA 3243.

MR 3900 SEMINAR IN METEOROLOGY (2-0). Students present original research or prepare summaries of recent findings in the field of meteorology and present synopses for group discussion. PREREQUISITE: Graduate courses.

MR 4240 ADVANCED ATMOSPHERIC ANALYSIS (3-0). Advanced diagnostic techniques; vertical motion schemes including generalized omega equation and filtered vorticity and kinematic techniques; parcel dynamics along trajectories. Mesoscale

analysis; application to severe storms and squall lines. Developments in atmospheric sensory systems; temperature profile determination and cloud motion from satellites, constant pressure balloons. PREREQUISITE: MR 4323.

MR 4242 ADVANCED TROPICAL METEOROLOGY (3-0). Scale analysis of tropical motions; large-scale wave spectra; observations and dynamics of near-equatorial stratospheric flows to include boundary-layer considerations; dynamics and thermodynamics of tropical disturbances, particularly severe tropical cyclones. PREREQUISITES: MR 3250 or consent of Instructor.

MR 4250 GENERAL CIRCULATION OF THE ATMOSPHERE. (3-0). Stability of zonal flows and implications for wave regimes; heat and momentum balances; mean meridional circulations; energetics of the general circulation; experimental models of the general circulation; implications for other rotating geophysical systems; trace substance transport by large scale atmospheric processes; numerical models of the general circulation. PREREQUISITE: MR 4323.

MR 4321 INTRODUCTORY GEOPHYSICAL FLUID DYNAMICS (4-0). Development of the hydrodynamical equations, victor and tensor operations, forces acting on fluids (surface forces, body forces). Stream function, velocity potential, geostrophic, gradient and inertial flows. Baroclinic and barotropic fluids, vertical variation of horizontal velocity, Ekman spiral applied to ocean and atmosphere. Geopotential surfaces, level of motion: Vorticity and divergence equations. TEXT: Haltiner and Martin, *Dynamical and Physical Meteorology;* Stommel, *The Gulf Stream.* PREREQUISITES: MA 2047, MA 2121, MR 3420.

MR 4322 DYNAMIC METEOROLOGY (4-0). Scale analysis, perturbation method; solutions of equations of motion for simple sound, gravity, and synoptic waves; filtering; baroclinic and barotropic instability; energy equations, integral constraints. TEXT: Haltiner and Martin, *Dynamical and Physical Meteorology;* departmental notes. PREREQUISITE: MR 4321.

MR 4323 NUMERICAL WEATHER PREDICTION (4-3). Objective analysis, barotropic and baroclinic models; vertical velocity; finite-difference equations; computational instability; boundary conditions; relaxation techniques, inclusion of heat, friction and moisture; energetics and general circulation models. TEXTS: Haltiner, *Numerical Weather Prediction;* U.S. Naval Weather Service Manual for Computer Products. PREREQUISITES: MR 4322, MA 3243 concurrently.

MR 4324 ADVANCED NUMERICAL WEATHER PREDICTION (3-0). Initialization, boundary conditions, finite difference schemes, stability and convergence; sensible, latent, and radiative heat transfer; simulation of sub-grid scale processes such as convection and friction; general circulation models, spectral methods. PREREQUISITE: MR 4323 or consent of Instructor.

MR 4331 ADVANCED GEOPHYSICAL FLUID DYNAMICS I (3-0). Dynamics of a homogeneous layer of fluid in a rotating system; scale analysis, dispersion and group velocity; barotropic and baroclinic instability — the discrete and the continuous spectrum of eigenvalues, boundary layer analysis with application in oceanography. PREREQUISITE: Consent of Instructor.

MR 4332 ADVANCED GEOPHYSICAL FLUID DYNAMICS II (3-0). Thermal convection — infinitesimal and finite amplitude; mountain waves and energy propagation; energy cascade; fluid spin up through Ekman layers. PREREQUISITE: Consent of Instructor.

MR 4412 HEAT TRANSFER PROCESSES (4-0). Monochromatic intensity and flux from black bodies; other properties of black bodies. The radiative transfer integral for flux crossing an arbitrary level in an atmosphere of water-vapor alone; of carbon-dioxide alone; the correction for overlap-effects when both are present. Terrestrial flux-divergency as cooling effect in the atmosphere. Solar insolation at the outer boundary of the atmosphere; at the ground; parameterization of extinction processes in the atmosphere. The albedo effects. The mean heat balance of the earth and atmosphere. Net radiative energy as a drive mechanism of the mean atmospheric motion systems. The Prandtl layer of constant eddy stress; of constant sensible-heat and water-vapor eddy-transfers near the earth's surface. TEXTS: Elsasser and Culbertson, *Atmospheric Radiation Tables;* Haltiner and Martin, *Dynamical and Physical Meteorology;* departmental notes. PREREQUISITE: MR 4321 concurrently.

MR 4413 AIR/SEA INTERACTION (4-0). Consequences of momentum, heat and moisture exchange between atmosphere and ocean. Recent semiempirical formulae relating air/sea fluxes to large scale meteorological parameters. Concepts in turbulence and similarity theory for stationary turbulent regimes adjacent to the air/sea interface. Turbulence sensors, bulk aerodynamic formulae for estimating air/sea boundary fluxes. Mutual atmosphere and ocean response times and synoptic scale energy exchanges. Investigations of the role of the atmosphere and oceans to global energy balance and climate formation. TEXTS: Lumley and Panofsky, *The Structure of Atmospheric Turbulence;* selected publications. PREREQUISITES: MR 4322, or OC 4252 and OC 3150 or consent of Instructor.

MR 4415 ATMOSPHERIC TURBULENCE (3-0). Approaches for defining the structure of the turbulent atmospheric boundary layer. Review of statistical descriptions of atmospheric turbulence; averaging, moments, joint moments, spectral representation. Equations for a turbulent regime in a stratified, shear flow. Scaling parameters and similarity theories for surface layer profiles, spectra: Kolmogorov hypotheses, Monin-Obukhov stability length. Measurement of atmospheric turbulence. Examination of observed spectra and scales of atmospheric turbulence. TEXT: Lumley and Panofsky, *The Structure of Atmospheric Turbulence.* PREREQUISITE: MR 4322, OC 3150.

MR 4422 UPPER ATMOSPHERE PHYSICS (3-0). Composition, temperature, and wind above 30 km. Physics and chemistry of ozonosphere and ionosphere. Atmospheric tides, earth's magnetic field, air-glow. Van Allen belts. TEXTS: Craig, *The Upper Atmosphere;* Massey and Boyd, *The Upper Atmosphere;* departmental notes. PREREQUISITE: MR 4412.

MR 4800 ADVANCED TOPICS IN ANALYSIS AND PREDICTION (3-0). Topics will be chosen to meet departmental and student needs. These topics may include geophysical fluid dynamics, tropical analysis and prediction systems, general circulation modelling of the air-ocean system, remote sensing. The course may be repeated for credit as topics change. PREREQUISITE: MR 4322 and consent of Department Chairman.

MR 4900 SEMINAR IN METEOROLOGY (2-0). Students present results of their thesis or other approved research investigation. PREREQUISITE: Concurrent preparation of thesis or other acceptable research paper.

DEPARTMENT OF OCEANOGRAPHY

DALE FREDERICK LEIPPER, Professor of Oceanography; Chairman (1968)*; B.S., Wittenberg University, 1937; M.A., Ohio State University, 1939; Ph.D., Scripps Institution of Oceanography (La Jolla), 1950; Hon. D.Sc., Wittenberg University, 1968.

ROBERT SANBORN ANDREWS, Assistant Professor of Oceanography (1968); B. of Geol. Engr., University of Minnesota, 1958; M.S., University of Washington, 1965; Ph.D., Texas A&M University, 1970.

CHARLES HOWARD BASSETT, JR., Lieutenant Commander, U. S. Navy; Instructor in Oceanography (1970); B.S., West Virginia University, 1956; B.S., Naval Postgraduate School, 1964; M.S., 1965.

NOEL EDWARD JAMES BOSTON, Associate Professor of Oceanography (1968); B.A.Sc., University of British Columbia, 1959; M.S., Texas A&M University, 1963; Ph.D., University of British Columbia, 1970.

ROBERT HATHAWAY BOURKE, Assistant Professor of Oceanography (1971); B.S., Naval Academy, 1960; M.S., Oregon State University, 1969; Ph.D., 1972.

WARREN WILSON DENNER, Associate Professor of Oceanography (1964); B.S., Portland State College, 1961; M.S., Oregon State University, 1963; Ph.D., 1969.

JERRY ALAN GALT, Assistant Professor of Oceanography (1970); B. S., University of Washington, 1963; M.S., 1967; B.S., 1968; Ph.D., 1969.

EUGENE CLINTON HADERLIE, Professor of Oceanography (1965); A.B., University of California at Berkeley, 1943; M.A., 1948; Ph.D., 1950.

GLENN HAROLD JUNG, Professor of Oceanography (1958); B.S., Massachusetts Instite of Technology, 1949; M.S., 1952; Ph.D., Texas A&M University, 1955.

WILLIAM CLIFTON KNODLE, Commander, U. S. Navy; Instructor in Oceanography (1970); B.S., Naval Academy, 1957; M.S., Naval Postgraduate School, 1964.

ROBERT GEORGE PAQUETTE, Associate Professor of Oceanography (1971); B.S., University of Washington, 1936; Ph.D., 1941.

CHARLES KEITH ROBERTS, Lieutenant Commander, U. S. Navy; Instructor in Oceanography (1971); B.S., Naval Academy, 1960; M.S., Naval Postgraduate School, 1968.

WARREN CHARLES THOMPSON, Professor of Oceanography (1953); B.A., University of California at Los Angeles, 1943; M.S., Scripps Institution of Oceanography, 1948; Ph.D., Texas A&M University, 1953.

EDWARD BENNETT THORNTON, Assistant Professor of Oceanography (1969); B.A., Willamette University, 1962; B.S., Stanford University, 1962; M.S., Oregon State University, 1965; M.E.C.E., University of Florida, 1966; Ph.D., 1970.

EUGENE DEWEES TRAGANZA, Associate Professor of Oceanography (1970); B.A., Indiana University, 1955; M.S., Texas A&M University, 1959; Ph.D., University of Miami, 1966.

JOSEPH JOHN VON SCHWIND, Associate Professor of Oceanography (1967); B.S., University of Wisconsin, 1952; M.S., University of Utah at Salt Lake City, 1960; Ph.D., Texas A&M University, 1968.

JACOB BERTRAM WICKHAM, Associate Professor of Oceanography (1951); B.S., University of California at Berkeley, 1947; M.S., Scripps Institution of Oceanography, 1949.

* *The year of joining the Postgraduate School Faculty is indicated in parentheses.*

Oceanography is the study of the sea from the points of view of the basic sciences: physics, biology, chemistry, and geology. The Department of Oceanography is the center for such studies at the Navy Postgraduate School. Its functions are to prepare officers to make best use of the ocean environment in the course of their duties, to prepare them to carry out and evaluate research in oceanography, and to carry out oceanographic research of both basic and/or applied nature.

The curriculum and research vessels are sponsored by the Oceanographer of the Navy. Research is supported by grants from various government agencies including the Office of Naval Research.

DEPARTMENTAL REQUIREMENTS FOR DEGREES IN OCEANOGRAPHY

BACHELOR OF SCIENCE WITH MAJOR IN OCEANOGRAPHY

1. The degree of Bachelor of Science with major in Oceanography requires completion of:
   a. A minimum of eleven quarter hours in upper division mathematics.
   b. Five quarter hours in meteorology.
   c. Four quarter hours in computer science.
   d. Twenty quarter hours in oceanography courses including descriptive, biological, chemical, and geological oceanography.
2. The entire sequence of courses selected must be approved by the Department of Oceanography.

MASTER OF SCIENCE IN OCEANOGRAPHY

Entrance to a program leading to the degree of Master of Science in Oceanography requires a baccalaureate degree in a field appropriate to the oceanography option chosen. Minimal requirements include mathematics through differential and integral calculus, one year of college physics, and one year of college chemistry.

The degree of Master of Science in Oceanography requires:

a. Completion of thirty-five quarter hours of graduate courses of which fifteen hours must be in the 4000 Oceanography series. The entire sequence of courses for the particular option selected must be approved by the Department of Oceanography.

b. An acceptable thesis on a topic approved by the Department of Oceanography.

DOCTOR OF PHILOSOPHY

The Department of Oceanography considers for Ph. D. studies only students who have received their Bachelor's or Master's degree in one of the sciences or in engineering. Such students register for graduate work in the Department of Oceanography and comply with both department and school-wide requirements for the degree of Doctor of Philosophy. Their work is directed by an appropriate faculty member of the Department of Oceanography. On fulfilling the requirements they receive their degrees in oceanography with specialization in physical oceanography.

Because of the interdisciplinary nature of oceanography, under special circumstances, cooperative programs may be arranged with other departments. Several departments are including oceanography courses in their programs and are engaged on research projects related to the marine environment. Students wishing to participate in cooperative programs should indicate the direction of their interests so that the appropriate departments may be consulted.

Details of the requirements for admission to graduate study at the Naval Postgraduate School may be found elsewhere in this catalogue. The details of offerings in oceanography are in the latter part of this section.

Department of Oceanography admission requirements for the degree of Doctor of Philosophy are

(a) a Master's degree (or the equivalent)

or (b) a Bachelor's degree with a high QPR

or (c) a successful first graduate year on a Master's program, with clear evidence of research ability.

For the Ph. D. after the Master's, the program of study includes course work and preparation of a thesis embodying the results of original and independent research. The total amount of course work is determined by the candidate's committee and school requirements.

Candidates who are permitted to proceed to the Ph. D. directly from the Bachelor's degree must complete three quarters of course work of a minimum of 36 hours (approximately 9 courses) at the 4000 level, obtaining A's in at least 24 hours (6 courses) and B's in the remaining.

Candidates must demonstrate competence in the English language and in such other languages as their committee recommends and the Naval Postgraduate School requires.

A student who desires to undertake doctoral work in oceanography should discuss his program first with the Chairman, Department of Oceanography. He should then consult the Curricular Officer for Environmental Sciences and follow regular guidelines as outlined by the Curricular Officer and the Academic Associate. A preliminary program will then be arranged. Following successful completion of the preliminary program a committee will be formed and a detailed program formulated.

LABORATORY FACILITIES

Four jointly utilized meteorological/oceanographic laboratories are served by a closed circuit television network. Two beachfront laboratories are also maintained, a small biological oceanography laboratory with salt water aquaria and filtered salt water circulating system, and a 4,000 square-foot laboratory with lecture room and student study areas. Equipment includes a wave tank, drying oven, and high pressure test chamber. Additionally, a small ocean engineering laboratory, chemical oceanography laboratory, and geological oceanography laboratory are maintained.

The School operates the R/V ACANIA, a 126-foot vessel, for use in oceanographic instruction and research. For approximately eight weeks each year use is made of AGOR vessels operated by the Naval Oceanographic Office for student indoctrination and for research by students and faculty.

Oceanographic equipment installed in the beach area includes a wave gauge and a tide gauge for recording nearshore wave action and local tide fluctuations.

OCEANOGRAPHY

OC 0110 FACULTY SEMINAR (1-0). An introduction to the faculty. Purpose is to hear descriptions of research and teaching interests of the members of both faculties (Meteorology and Oceanography) as an orientation and as a first opportunity for exposure to possible thesis research areas. Presentations by individual faculty members. PREREQUISITE: Enrollment in Environmental Sciences Curriculum.

OC 0810 THESIS RESEARCH (0-0). Every student conducting thesis research will enroll in this course.

Upper Division Courses

OC 2110 INTRODUCTION TO OCEANOGRAPHY (3-0). An introductory course treating physical and chemical properties of sea water, submarine geology, and marine biology; the heat budget of the oceans; water masses and general circulation; currents, waves, and tides. TEXT: Duxbury, *The Earth and Its Oceans.* PREREQUISITE: None.

OC 2120 SURVEY OF OCEANOGRAPHY (4-0). Beginning physical oceanography. An early consideration of subjects which cannot be handled fully until late in the curriculum, particularly biological, geological, and chemical oceanography, average values of ocean parameters, an integrated view of the whole field of oceanography. TEXT: Duxbury, *The Earth and Its Oceans.* PREREQUISITE: Enrollment in Environmental Sciences Curriculum.

OC 2420 PRINCIPLES OF MEASUREMENT (3-2). The application of the basic principles of mechanics, heat, electricity, sound and optics to meteorological instrumentation employed by the Navy with special emphasis on upper air and satellite developments; design and operation of oceanographic instruments; recording of oceanographic observations. TEXTS: Middleton and Spilhaus, *Meteorological Instruments;* H. O. 607; departmental notes. PREREQUISITE. MA 2121.

Upper Division or Graduate Courses

OC 3150 GEOPHYSICAL RANDOM PROCESSES (3-1). Statistical evaluation of measurements in random media: ocean, atmosphere, earth; basic probability, probability distributions, probability density functions; random variables, random functions; harmonic analysis of random functions. Time series analysis: covariance, convolution, enegy density spectrum, cross spectrum. TEXT: Bendat and Piersol, *Measurement and Analysis of Random Data;* departmental notes. PREREQUISITES: MA 2121, MA 3232, MA 3132, and MR 2420 or OC 2420.

OC 3221 DESCRIPTIVE PHYSICAL OCEANOGRAPHY (4-0). Properties of sea water; distribution of temperature, salinity, and oxygen; heat budget of the oceans; water masses and the three-dimensional circulation of the oceans; currents, waves, and tides. TEXTS: Pickard, *Descriptive Physical Oceanography;* McLellan, *Elements of Physical Oceanography.* PREREQUISITE: None.

OC 3250 DYNAMICAL OCEANOGRAPHY (4-0). Properties of sea water, the equations of motion in rotating frame of reference; special cases of motion; geostrophic, intertial, frictional flow, etc., turbulence and mixing; convection; models of general circulation; current measurements, direct and indirect. TEXT: Neuman and Pierson, *Principles of Physical Oceanography.* PREREQUISITES: MA 3132 concurrently; OC 3221.

OC 3260 SOUND IN THE OCEAN (3-0). Designed for students in the meteorology curricula. A brief introduction to physics of underwater acoustics followed by detailed discussion of oceanographic factors affecting sound transmission in the ocean including absorption, reflection from the surface and from the bottom, refraction, scattering, and ambient noise. TEXT: Urick, *Principles of Underwater Sound for Engineers.* PREREQUISITE: OC 2110 or OC 2120.

OC 3261 OCEANOGRAPHY FACTORS IN UNDERWATER SOUND (3-0). Primarily for Engineering Acoustics curriculum. Review of envirmonmental factors arising from the biology, chemistry, geólogy and physics of the ocean which affect sound propagation, and discussion of their influence on sound propagation. TEXT: Departmental notes; selected references. PREREQUISITES: OC 3221, CH 1001, CH 1002, PH 3452 or equivalents.

OC 3279 CASE STUDIES IN ENVIRONMENTAL SUPPORT (0-4). Laboratory experience in the application of oceanographical and meteorological analysis and prediction in support of Naval strategy and tactics, emphasizing the planning, execution and situation analysis of Naval operations from an environmental viewpoint. TEXTS: NAV Wea Serv Com Support Manual, NWS 3360/1; departmental notes; NOAA, DWS and AWS publications. PREREQUISITES: OC 3616 and OC 3621 concurrently; and OC 3611, OC 3615, MR 3260 and MR 3265; or OC 4601, OC 3605, MR 3240 and MR 3245.

OC 3320 GEOLOGICAL OCEANOGRAPHY (3-3). General geological principles; physiography of the sea floor, especially contincntal shelves and slopes, submarine canyons, coral reefs, and the deep-sea floor; properties and distribution of sediments and dates of deposition; structure and origin of the ocean basins. TEXT: Foster, *Geology;* Shepard, *Submarine Geology.* PREREQUISITE: None.

OC 3321 MARINE GEOPHYSICS (3-0). Gravity, magnetism seismicity, and other geophysical characteristics of the oceans and sea floor; physical properties and composition of the sea floor; structure of the earth's crust and upper mantle; origin of the ocean basins and formation of major sea-floor features. TEXTS: Dobrin, *Geophysical Prospecting, 2nd ed.;* selected publications. PREREQUISITE: OC 3320.

OC 3420 BIOLOGICAL OCEANOGRAPHY (3-3). General biological principles; the sea as an environment for life; major plant and animal groups in the sea; plankton and food cycles; primary productivity; boring and fouling organisms; bioacoustics, bioluminescence, and deep scattering layers; dangerous marine organisms; physiology of shallow water diving. Laboratory work and field trips dealing with marine organisms. TEXTS: McConnaughy, *Introduction to Marine Bioology;* Hedgpeth, *Seashore Life of the San Francisco Bay region and the Coast of Northern California.* PREREQUISITE: None.

OC 3520 CHEMICAL OCEANOGRAPHY (3-2). Basic chemistry of solutions; chemical compositions of the oceans (dissolved solids, gases, nutrients, etc.); distribution of constituents in the ocean; analytical methods used in chemical oceanography; carbonate, nutrient, and other cycles in the sea; desalination; corrosion, geochemistry. TEXTS: Strickland and Parsons, *A Manual for Sea Water Analysis;* Riley, *An Introduction to Marine Chemistry.* PREREQUISITES: OC 3221, CH 1001 or CH 2001 or equivalent.

OC 3605 OCEAN WAVE FORECASTING LABORATORY (0-4). Laboratory course taught in conjunction with OC 4601. Exercises in wave observation, the analysis of wave records, wave forecasting from known wind fields derived from weather maps. TEXT: H. O. Pub. 603. PREREQUISITE: Consent of Instructor.

OC 3611 OCEAN WAVE AND SURF FORECASTING (2-0). Course designed for students in the meteorology curricula. Statistical and spectral properties of waves; wave observations and analysis of wave records; the generation, propagation and attenuation of sea and swell; techniques used in the forecasting of sea and swell; transformation of waves in shallow water. TEXT: H. O. Pub. 603 and H. O. Pub. 234. PREREQUISITE: OC 2110 or OC 2120.

OC 3615 OCEAN WAVE AND SURF FORECASTING LABORATORY (0-4). Laboratory course taught in conjunction with OC 3611. Exercises in forecasting sea and swell generated under various synoptic weather conditions and in surf forecasting. TEXT: H. O. Pub. 603 and H. O. Pub. 234. PREREQUISITE: OC 3611 concurrently.

OC 3616 ACOUSTICAL FORECASTING (3-0). Space and time variation of ocean density structure and associated parameters; behavior of vertical and horizontal temperature gradients; development of synoptic forecasting techniques applied to the upper ocean; air-sea interaction; advection and mixing effects on ocean density structure. Interpretation in terms of sound propagation paths and sonar range. TEXTS: Class notes; selected publications. PREREQUISITE: OC 3260 or OC 4260.

OC 3621 ACOUSTICAL FORECASTING LABORATORY (0-4). Laboratory exercises illustrate principles developed in OC 3616 using actual air and ocean data, available forecasting techniques (ASWEPS, and others), and range manuals. Forecasting of sea surface temperature, mixed-layer depth, and sonar range. TEXT: Selected publications. PREREQUISITE: OC 3616 concurrently.

OC 3709 SCIENTIFIC CRUISE EXPERIENCE (0-4). Laboratory course taught to introduce the student to oceanographic operations at sea. The use of standard oceanographic instruments is stressed in the conduct of a comprehensive oceanographic survey; processing of data and storage of data and samples are studied and accomplished. Interpretation of results is introduced. TEXTS: H. O. 607; selected publications. PREREQUISITES: OC 2420 and OC 2110 or OC 2120 or OC 3221.

OC 3710 OCEANOGRAPHIC CRUISE PLANNING AND FIELD EXPERIENCE (2-4). This course gives comprehensive coverage of planning for oceanographic surveys and of interpreta-

ion and reporting of results. Included is a brief summary of hydrographic (charting) surveys. Field experience begun in OC 3709 is continued with students participating extensively in cruise planning. The cruise is scheduled for near mid-term; and after completion of at-sea operations, a report of survey is prepared. TEXTS: H. O. 607; selected references. PREREQUISITES: OC 3709, OC 3320, OC 3420 and OC 3520 concurrently.

OC 3801 OCEAN OPERATIONS I (3-1). This course includes a comprehensive coverage of the present state-of-the-art associated with types of floating platforms; stationary platforms; submersible design, operation, and applications; manipulator design; diving operations; underwater construction and structures; energy sources; pressure vessels and testing programs; unmanned vehicles and platforms; deep drilling; dynamic positioning; buoys and deep water buoyancy; in general those operations associated with search, rescue, recovery, and salvage. Field trips made to laboratories deeply involved in oceanographic engineering work. TEXT: Bratz, *Ocean Engineering.* PREREQUISITES: None.

Graduate Courses

OC 4211 WAVES AND TIDES (4-0). Linear theory of surface and internal waves; theory of finite amplitude waves; wind-wave spectra; theory of the astronomical tides; tide analysis and prediction; seiches and co-oscillations. TEXT: Kinsman, *Wind Waves.* PREREQUISITE: OC 4321 or MR 4321 or ME 2201.

OC 4213 COASTAL OCEANOGRAPHY (3-1). Shoal-water wave processes, breakers and surf; nearshore water circulations; beach characteristics; littoral drift; coastal hydraulics, storm tides. TEXT: Ippen, *Estuary and Coastline Hydrodynamics,* or appropriate substitution. PREREQUISITE: OC 4211.

OC 4260 SOUND IN THE OCEAN (3-0). Oceanographic effects on sound propagation, especially on absorption, reflection, refraction; scattering, ambient noise; operational aspects for Navy use. TEXTS: Departmental notes: selected references. PREREQUISITES: PH 3431 or equivalent and OC 3221.

OC 4321 INTRODUCTORY GEOPHYSICAL FLUID DYNAMICS (4-0). Development of the hydrodynamical equations, vector and tensor operations, forces acting on fluids (surface forces, body forces); stream function, velocity potential, geostrophic, gradient and inertial flows; baroclinic and barotropic fluids, vertical variation of horizontal velocity; Ekman spiral applied to ocean and atmosphere; geopotential surfaces, level of no motion; vorticity and divergence equations. TEXTS: Haltiner and Martin, *Dynamical and Physical Meteorology;* Stommel, *The Gulf Stream.* PREREQUISITES: MA 2047, MA 2121, MR 3420.

OC 4322 OCEAN CIRCULATION (4-0). The wind-driven ocean circulation, real fluid boundary conditions, steady-state linear theories, steady-state non-linear theories, vorticity arguments; topographical influence on ocean currents, significance of inertial and frictional terms in an ocean with bottom topography; time dependent motion, Rossby waves. TEXTS: Stommel, *The Gulf Stream;* Robinson, *Wind-driven Ocean Circulation;* selected papers. PREREQUISITE: OC 4321.

OC 4323 HYDROTHERMODYNAMICS (3-0). Development of the fundamental equations of hydrothermodynamics as applied to seawater; conservation of total energy, first and second laws of thermodynamics for fluid mixtures, entropy; equation of state for seawater; transport phenomena, special laws of non-advective transfer of properties. TEXT: Selected references. PREREQUISITE: OC 4322.

OC 4413 AIR-SEA INTERACTION (3-0). Consequences of momentum, heat and moisture exchange between atmosphere and ocean; recent semi-empirical formulae relating air-sea fluxes to large-scale meterological parameters; concepts in turbulence and similarity theory for stationary turbulent regimes adjacent to the air-sea interface; turbulence sensors, bulk aerodynamic formulae for estimating air-sea boundary fluxes; mutual atmosphere and ocean response times and synoptic scale energy exchanges; investigations of the role of the atmosphere and oceans of global energy balance and climate formation. TEXTS: Lumley and Panofsky, *The Structure of Atmospheric Turbulence;* selected publications. PREREQUISITES: OC 3150, OC 4322 or MR 4322, or consent of Instructor.

OC 4421 MARINE ECOLOGY (1-4) The habits, classification, development and adaptations of marine animals and plants with particular reference to ecology of Monterey Bay. The relationships of physical, chemical, geological, and biological factors of the environment to marine organisms. Primarily laboratory investigations and field work dealing with the intertidal areas, harbors, estuaries, and the near-shore pelagic and benthic environments of the associated organisms. TEXT: Ricketts and Calvin, *Between Pacific Tides.* PREREQUISITE: OC 3420.

OC 4422 MARINE BIODETERIORATION (1-1). A study of the organisms involved in the bio-deterioration of engineering materials. Subjects included are marine fouling, wood and rock borers, and the effects of biological organisms on the corrosion of metals. TEXT: Class notes. PREREQUISITE: OC 3420.

OC 4601 OCEAN WAVE FORECASTING (3-0). Statistical and spectral properties of ocean waves, the generation, propagation, and attenuation of surface wind waves in deep water; spectral and other forecasting techniques; wave observations and analysis. TEXTS: Kinsman, *Wind Waves;* H. O. Pub. 603. PREREQUISITE: OC 4211.

OC 4612 POLAR OCEANOGRAPHY (3-2). Oceanographic and geophysical structure of the polar regions; sea-ice properties, formation, growth, deformation and disintegration; sea-ice drift due to wind and currents. The course is frequently conducted as a two-week course with field experience at the Naval Arctic Research Laboratory, Barrow, Alaska. Laboratory studies of the physical, chemical, petrographic structure and strength properties are conducted. TEXT: Pounder, *Physics of Ice;* selected papers. PREREQUISITE: None.

OC 4800 SPECIAL TOPICS IN OCEANOGRAPHY (3-0). Independent study of advanced topics in oceanography not regularly offered. PREREQUISITE: Consent of the department chairman and instructor.

OC 4802 OCEAN OPERATIONS II (3-1). Considerations of more complex aspects of oceanographic engineering operations, including such subjects as deep mooring techniques; platform and ship motions; large object towing forces; heavy lifts and line dynamics; wave loads on platforms and floating breakwaters; hydrodynamic aspects of falling objects; considerations of high pressure structural design; participation in a laboratory exercise involving conducting an oceanographic engineering operation at sea. TEXT: Class notes. PREREQUISITE: OC 3801.

OC 4803 PHYSICAL PROPERTIES OF MARINE SEDIMENTS (2-3). This course involves the elementary study of the physical behavior of marine sediments including such subjects as types of sediments, coring and testing equipment, general physical characteristics of sediments, methods of detailed physical and chemical analysis, in-situ testing, pressure effects, scour and fill, turbidity flows. Application is made to penetration and breakout of objects and to trafficability. TEXT: Class notes. PREREQUISITE: OC 3320.

OC 4851 GEOPHYSICS: EARTH GRAVITY (3-2). Study of the earth's gravity field, size and shape of the earth, deflection of the vertical, isostasy; gravity instruments, techniques, and data interpretation in geophysical exploration. Gravimetric field

urveys will be conducted in vicinity of Monterey. TEXTS: Heiskanan and Vening Meinesz, *The Earth and Its Gravity Field*; Garland, *The Earth's Shape and Gravity*; Dorbin, *Geophysical Prospecting*. PREREQUISITES: MA 3132 and MA 3181 or equivalent.

OC 4852 GEOPHYSICS: EARTH MAGNETISM AND ELECTRICITY (3-2). Introduction to the earth's magnetic and electrical fields; theory, instruments, and field techniques in magnetic and electrial exploration. Field work will be conducted. TEXTS: Jacob, *The Earth's Core and Geomagnetism*; Jakowsky, *Exploration Geophysics*. PREREQUISITES: MA 3132 and MA 3181 or equivalent.

OC 4853 GEOPHYSICS: SOUND AND SEISMICITY (4-0). Development of fundamental elastic wave equations; ray and normal mode theory; wave propagation in layered media; reflectivity, and attenuation; seismicity of the earth; mechanics of earthquakes; time-distance curves; geophysical interpretation of seismic records. TEXTS: Officer, *Introduction to the Theory of Seismology*; Grant and West, *Interpretation Theory in Applied Geophysics*. PREREQUISITE: OC 4260 or consent of the Instructor.

OC 4860 PHYSICS OF THE EARTH (3-0). Physical properties and composition of the earth's interior; review of the theories of the earth's formation; study of the crustal structure through gravity, magnetic, seismic, and other geophysical evidence. TEXTS: Gutenberg, *Physics of the Earth*; Jacobs, Russell and Wilson, *Physics and Geology*. PREREQUISITE: OC 3320 or consent of the Instructor.

OC 4900 SEMINAR IN OCEANOGRAPHY (2-0). Students in the various oceanography curricula report results of their own research in presentations for group discussion. PREREQUISITE: Preparation of a thesis or a research paper concurrently.

Research for the polar oceanography course on Ice Island T-3 in the Arctic Ocean off the coast of Alaska

Student from the polar oceanography course at the Naval Arctic Research Laboratory, Point Barrow, Alaska

DEPARTMENT OF OPERATIONS RESEARCH AND ADMINISTRATIVE SCIENCES

JACK RAYMOND BORSTING, Professor of Operations Research and Administrative Sciences; Chairman (1959)*; B.A., Oregon State University, 1951; M.A., University of Oregon, 1952; Ph.D., 1959.

ALVIN FRANCIS ANDRUS, Associate Professor of Operations Research and Statistics (1963); B.A., University of Florida, 1957; M.A., 1958.

JAMES KENICHI ARIMA, Associate Professor of Operations Research and Behavioral Science (1969); B.A., University of California at Los Angeles, 1948; M.A., George Washington Uuniversity, 1957; Ph.D., Northwestern University, 1962.

DONALD ROY BARR, Associate Professor of Operations Research and Statistics (1966); B.A., Whittier College, 1960; M.S., Colorado State University, 1962; Ph.D., 1965.

EAMON BOYD BARRETT, Associate Professor of Operations Research (1966); B.A., University of Oregon, 1953; M.A. 1958; Ph.D., Stanford University 1967.

RONALD STEPHENS BARDEN, Lieutenant, U. S. Naval Reserve; Assistant Professor of Accounting and Information Systems (1971); B.S., University of North Carolina, 1968; Ph.D., University of Texas, 1971.

ROBERT JO BEDOW, Lieutenant Commander, U. S. Navy; Instructor in Operations Research (1971); B.S., University of California at Berkeley; M.S., Naval Postgraduate School, 1967.

EDWARD ABE BRILL, Assistant Professor of Operations Research (1970); A.B., University of California at Los Angeles, 1966; M.S., Stanford University, 1967; Ph.D., 1970.

DAVID CARLO BURNS, Assistant Professor of Accounting and Management (1972); B.B.A., Univ. of Cincinnati, 1968; M.B.A., Indiana Univ., 1970; D.B.A., 1972.

RICHARD WESLEY BUTTERWORTH, Assistant Professor of Operations Research, (1969); B.S., University of California at Berkeley, 1966; M.S., 1967; Ph.D., 1969.

THOMAS DANFORTH BURNETT, Assistant Professor of Operations Research and Statistics (1969); B.S., Oregon State University, 1962; M.S., 1964; Ph.D., 1969.

JAMES ROBERT CAPRA, Lieutenant (junior grade), U. S. Naval Reserve; Instructor in Operations Research (1970); B.A., Georgetown University, 1968; M.S., Naval Postgraduate School, 1970.

PAUL MARSHALL CARRICK, Associate Professor of Management (1969); B.A., Northwestern University, 1949; Ph.D., University of California at Berkeley, 1956.

WILLIAM HOWARD CHURCH, Professor of Management (1956); B.A., Whittier College, 1933; M.S.P.A., University of Southern California, 1941.

JOHN WALLIS CREIGHTON, Professor of Management (1967); B.S., University of Michigan, 1938; B.A., Hastings College, 1939; Ph.D., University of Michigan, 1954.

WILLIAM PEYTON CUNNINGHAM, Distinguished Professor of Physics and Operations Research (1946); B.S., Yale University, 1928; Ph.D., 1932.

LESLIE DARBYSHIRE, Professor of Management (1962); B.A., University of Bristol, 1950; D.B.A., University of Washington, 1957.

PAUL EISENHARDT, Lieutenant, U. S. Naval Reserve; Instructor in Management (1969); B.S., Brown University, 1967; M.B.A., Harvard University, 1969.

RICHARD SANFORD ELSTER, Associate Professor of Management and Psychology (1969); B.A., University of Minnesota, 1963; M.A., University of Minnesota, 1965; Ph.D., 1967.

JAMES DANIEL ESARY, Associate Professor of Operaticns Research and Statistics, (1970); A.B., Whitman College, 1948; M.A., University of California at Berkeley, 1951; Ph.D., 1957.

ROBERT LEROY FERGUSON, Assistant Professor of Operations Research and Management (1969); A.B., Univ. of Kansas, 1956; D.B.A., Harvard Univ., 1970.

ROBERT NEAGLE FORREST, Associate Professor of Operations Research (1964); B.S., University of Oregon, 1950; M.S., 1952; M.S., 1954; Ph.D., 1959.

JAMES MORGAN FREMGEN, Professor of Accounting (1965); B.S.C., University of Notre Dame, 1954; M.B.A., Indiana University, 1955; D.B.A., 1961; C.P.A., State of Indiana, 1964.

DONALD PAUL GAVER, JR., Professor of Operations Research and Statics (1971); S.B., Massachusetts Institute of Technology, 1950; S.M., 1951; Ph.D., Princeton University, 1956.

WILLIAM HARVEY GITHENS, Visiting Associate Professor of Industrial Psychology (1969); B.S., Allegheny College, 1952; M.S., Western Reserve University, 1955; Ph.D., 1962.

HAROLD GREENBERG, Professor of Operations Research, (1967); B.A., Brooklyn College, 1949; M.S., New York University, 1958; Ph.D., 1964.

JAMES KERN HARTMAN, Assistant Professor of Operations Research (1970); B.S., Massachusetts Institute of Technology, 1965; M.S., University of Nebraska, 1967; Ph.D., Case Western Reserve University, 1970.

GEORGE EMIL HEIDORN, Assistant Professor of Operations Research and Computer Science (1968); B.M.E., General Motors Institute, 1962; M.S., Yale University, 1967; Ph.D., 1972.

JAMES EVERETT HIGGINS, Lieutenant (junior grade), U. S. Naval Reserve; Instructor in Operations Research (1969); B.S., North Carolina State University, 1967; M.S., Cornell University, 1969.

FENN CLARK HORTON, Associate Professor of Economics (1964); B.A., State University of Iowa, 1950; M.A., Claremont Graduate School, 1967; Ph.D., 1968.

H. ARTHUR HOVERLAND, Associate Professor of Administrative Sciences (1963); B.S., Miami University, 1951; M.S., University of Illinois, 1954; Ph.D., University of Michigan, 1963.

GILBERT THOREAU HOWARD, Associate Professor of Operations Research (1967); B.S., Northwestern University, 1963; Ph.D., Johns Hopkins University, 1967.

WILLIAM NICHOLAS HUNTER, Instructor in Management (1971); B.S., Northeastern University, 1962; M.B.A., University of Hartford, 1967.

JAMES PATRICK HYNES, Assistant Professor of Administrative Sciences (1969); B.A., University of Notre Dame, 1966; M.B.A., Michigan State University, 1967; Ph.D., 1971.

JAMES ALVIN JOLLY, Associate Professor of Administrative Sciences (1969); B.A., University of the Pacific, 1950; M.B.A., University of Santa Clara, 1963; Ph.D., 1970.

CARL RUSSELL JONES, Associate Professor of Operations Research and Administrative Sciences (1965); B.S., Carnegie Institute of Technology, 1956; M.B.A., University of Southern California, 1963; Ph.D., Claremont Graduate School, 1965.

GUNDAR JULIAN KING, Visiting Professor of Management (1971); B.A., J.W.v. Goethe University, 1946; B.B.A., University of Oregon, 1956; M.B.A., Stanford University, 1958; Ph.D., 1964.

MELVIN BERNARD KLINE, Professor of Management (1970); B.S., College of the City of New York, 1941; M.S., Stevens Institute of Technology, 1952; M.E., University of California at Los Angeles, 1959; Ph.D., 1966.

HAROLD JOSEPH LARSON, Associate Professor of Operation Research and Statistics (1962); B.S., Iowa State University, 1956; M.S., 1957; Ph.D., 1960.

PETER ADRIAN WALTER LEWIS, Professor of Operations Research and Statistics (1971); B.A., Columbia College, 1954; B.S., Columbia Engineering School, 1955; M.S., 1957; Ph.D., University of London, 1964.

GLENN FRANK LINDSAY, Associate Professor of Operations Research (1965); B.Sc., Oregon State University, 1960; M.Sc., Ohio State University, 1962; Ph.D., 1966.

KNEALE THOMAS MARSHALL, Associate Professor of Operations Research (1968); B.Sc., University of London, 1958; M.S., University of California, 1964; Ph.D., 1966.

JOE HOWARD MCDONALD, Lieutenant (junior grade), U. S. Naval Reserve; Instructor in Management (1969); B.A., Duke University, 1967; M.B.A., 1969.

ALAN WAYNE MCMASTERS, Associate Professor of Operations Research (1965); B.S., University of California, 1957; M.S., 1962; Ph.D., 1966.

PAUL ROBERT MILCH, Associate Professor of Operations Research and Statistics (1963); B.S., Brown University, 1958; Ph.D., Stanford University, 1966.

GERALD LEE MUSGRAVE, Assistant Professor of Administrative Sciences (1968); B.A., San Fernando Valley State College, 1964; M.S., Michigan State University, 1966; Ph.D., 1972.

CLAIR ALTON PETERSON, Associate Professor of Operations Research and Economics (1962); B.B.A., University of Minnesota, 1951; Ph.D., Massachusetts Institute of Technology, 1961.

GARY KENT POOCK, Assistant Professor of Operations Research and Man-Machine Systems (1967); B.S., Iowa State University, 1961; M.S., University of Miami, 1965; Ph.D., University of Michigan, 1967.

FRED LORENZO PRESTON, JR., Lieutenant (junior grade), U. S. Naval Reserve; Instructor in Operations Research (1969); B.A., DePauw University, 1967; M.S., Case Western Reserve University, 1969.

WILLIAM MICHAEL RAIKE, Associate Professor of Operations Research (1971); B.A., Northwestern University, 1964; M.S., 1965; Ph.D., 1967.

ROBERT RICHARD READ, Professor of Operations Research, Probability and Statistics (1961); B.S., Ohio State University, 1951; Ph.D., University of California at Berkeley, 1957.

FRANCIS RUSSELL RICHARDS, Assistant Professor of Operations Research (1970); B.S., Louisiana Polytechnic Institute, 1965; M.S., Clemson University, 1967; Ph.D., 1971.

NORMAN FLOYD SCHNEIDEWIND, Professor of Information Systems and Administrative Sciences (1971); B.S., University of California at Berkeley, 1951; M.B.A., University of Southern California, 1960; D.B.A., 1966.

DAVID ALAN SCHRADY, Associate Professor of Operations Research (1965); B.S., Case Institute of Technology, 1961; M.S., 1963; Ph.D., 1965.

JOHN DAVID SENGER, Associate Professor of Management and Behavioral Sciences (1967); B.S., University of Illinois, 1945; M.S., 1948; Ph.D., 1965.

BRUNO OTTO SHUBERT, Assistant Professor of Operations Research (1970); M.S., Czechoslovakia Technical University at Prague, 1960; ,Ph.D. Charles University at Prague, 1964; Ph.D., Stanford University, 1968.

REX HAWKINS SHUDDE, Associate Professor of Operations Research (1962); B.S., University of California at Los Angeles, 1952; Ph.D., University of California at Berkeley, 1956.

JOHN HENRY SMITH, Lieutenant Colonel, U. S. Marine Corps; Assistant Professor of Management (1970); B.S., Naval Academy, 1953; M.S., Naval Postgraduate School, 1970.

MICHAEL GRAHAM SOVEREIGN, Associate Professor of Operations Research (1970); B.S., University of Illinois, 1959; M.S., Purdue University, 1960; Ph.D., 1965.

MELVIN JOHN STECKLER, Associate Professor of Management (1966); B.S., University of Washington, 1949; M.B.A., 1957; D.B.A., Harvard University, 1967.

JAMES GROVER TAYLOR, Associate Professor of Operations Research (1968); B.S., Stanford University, 1961; M.S., 1962; Ph.D., 1966.

MARLIN ULUESS THOMAS, Assistant Professor of Operations Research (1971); B.S., University of Michigan, 1967; M.S.E. 1968; Ph.D., 1971.

JOSEPH BRYCE TYSVER, Associate Professor of Operations Research and Statistics (1966); B.A., Washington State University, 1942; M.A., 1948; Ph.D., University of Michigan, 1957.

RUSSELL SHELBY UHLER, Visiting Associate Professor of Economics (1971); B.A., Fresno State College, 1960; Ph.D., Claremont Graduate School, 1967.

ALAN ROBERT WASHBURN, Assistant Professor of Operations Research (1970); B.S., Carnegie Institute of Technology, 1962; M.S., 1963; Ph.D., 1965.

RONALD ALFRED WEITZMAN, Associate Professor of Psychology (1971); B.A., Stanford University, 1952; M.A., 1954; Ph.D., Princeton University, 1959.

DAVID RICHARD WHIPPLE, JR., Assistant Professor of Operations Research and Economics (1971); B.A., University of St. Thomas, 1964; M.A., St. Mary's University, 1966; Ph.D., University of Kansas, 1971.

NORMAN KEITH WOMER, Lieutenant, U. S. Naval Reserve; Assistant Professor of Operations Research and Economics (1969); B.A., Miami University, 1966; Ph.D., Pennsylvania State University, 1970.

PETER WILLIAM ZEHNA, Professor of Operations Research and Statistics (1961); B.A., Colorado State College, 1950; M.A., 1951; M.A., University of Kansas, 1956; Ph.D., Stanford University, 1959.

HANS JACOB ZWEIG, Associate Professor of Operations Research and Statistics (1970); B.A., University of Rochester, 1949; M.A., Brown University, 1952; Ph.D., Stanford University, 1963.

* *The year of joining the Postgraduate School Faculty is indicated in parentheses.*

DEPARTMENTAL REQUIREMENTS FOR DEGREES

Programs leading to degrees must be arranged in consultation with the Chairman, Department of Operations Research and Administrative Sciences.

BACHELOR OF SCIENCE WITH MAJOR IN BUSINESS ADMINISTRATION

A candidate for the Bachelor of Science degree with a major in business administration must meet the general requirements for the baccalaureate degree. Additionally, he must meet the following specific requirements for the major:

a. A minimum of 34 quarter hours of course work at or above the 2000 level.

b. Successful completion or validation by advanced credit of approved courses in each of the following areas of study:
   - Behavioral Sciences
   - Computers and Programming
   - Economics
   - Financial Management and Accounting
   - Material Management
   - Statistics
   - Operations Research

BACHELOR OF SCIENCE IN OPERATIONS RESEARCH

1. The basic requirements for the degree of Bachelor of Science in Operations Research consists of a minimum of 60 upper division quarter hours at the Naval Postgraduate School and including at least:
   a. 36 quarter hours of operations research systems analysis and probability and statistics.
   b. 12 quarter hours outside the Department of Operations Research and Administrative Sciences.

2. The student must maintain a QPR of at least 2.2 in courses offered by the Department of Operations Research and Administrative Sciences.

MASTER OF SCIENCE IN COMPUTER SYSTEMS MANAGEMENT

1. A candidate for the degree of Master of Science in Computer Systems Management must complete satisfactorily either (A) a minimum of 56 quarter hours of graduate level course work or (B) a minimum of 48 quarter hours of graduate level course work and an acceptable thesis.

2. Core course requirements at the graduate level must be successfully completed or validated by advanced credit in each of the following areas:
   - Computer Scicence
   - Data Processing
   - Economics
   - Financial Management and Accounting
   - Material Management
   - Operations Research
   - Statistics

MASTER OF SCIENCE IN MANAGEMENT

1. A candidate for the degree of Master of Science in Management must complete satisfactorily either (a) a minimum of 56 hours of graduate level work with 16 hours at the 4000 level, or (b) a minimum of 48 hours of graduate level work, with 8 hours at the 4000 level, and a thesis. The set of requirements to be fulfilled depends upon the curricular area in which the student is enrolled.

2. Degree requirements for all of the majors in management must include completion of at least one graduate level course in each of the following areas of study:

Economics
Probability and Statistics
Financial Management
Behavioral Sciences
Management Theory
Operations Research

3. In addition to the subject area requirements listed in paragraph 2, each candidate must fulfill the requirements of one of the following sequences:

Personnel Management
Sixteen or more quarter hours at the graduate level in approved personnel management courses.

Financial Management
Sixteen or more quarter hours at the graduate level in approved financial management courses.

Material Management
Sixteen or more quarter hours at the graduate level in approved courses in the area of material management.

Management Science
Sixteen or more quarter hours at the graduate level in approved courses in quantitative management or operations analysis.

Economics
Sixteen or more quarter hours at the graduate level in approved economics courses.

Communications Management
Sixteen or more quarter hours at the graduate level in approved courses in computer science, data processing, and material management, plus an approved sequence of courses in electrical engineering and communications.

Weapons Systems Acquisition
Twenty-eight or more quarter hours of 4000 level work in approved project management courses.

MASTER OF SCIENCE IN OPERATIONS RESEARCH

1. A candidate shall previously have satisfied the requirements for the degree of Bachelor of Science in Operations Research or the equivalent.

2. Completion of a minimum of 48 quarter hours of graduate-level courses, including at most 8 quarter hours for a thesis.

a. At least 18 quarter hours of 4000 level operations research/systems analysis courses.

b. An elective sequence approved by the Department of Operations Research and Administrative Sciences.

3. Submission of an acceptable thesis on a subject previously approved by the Department of Operations Research and Administrative Sciences. This credit shall not count toward the requirement stated in 2a.

DOCTOR OF PHILOSOPHY

1. Students wishing to be considered for doctoral work in Operations Research should announce their intentions as early as possible, preferably by the fifth quarter. The department chairman will examine the applicant's qualifications, modify his second year program, and monitor his progress. The schoolwide requirements are contained in the General Information section of this catalogue.

2. If the applicant is selected, he must pursue a course of in-depth study in mathematical programming, stochastic processes and a third area approved by his doctoral committee. He must be advanced to candidacy and write an acceptable thesis pertinent to an area of specialization selected from the following four: stochastic processes, mathematical programming, decision sciences, and human factors.

OPERATIONS RESEACH and ADMINISTRATIVE SCIENCES

CM 0001 SEMINAR FOR COMMUNICATIONS MANAGEMENT STUDENTS (0-2). Guest Lecturers. Thesis and research presentations. PREREQUISITE: None.

CT 0001 SEMINAR FOR COMPUTER SYSTEMS MANAGEMENT STUDENTS (0-2). Guest Lecturers. Thesis and research presentations. PREREQUISITE: None.

MN 0001 SEMINAR FOR MANAGEMENT STUDENTS (0-2). Guest Lecturers. Thesis and research presentations. PREREQUISITE: None.

OA 0001 SEMINAR FOR OPERATIONS RESEARCH/SYSTEMS ANALYSIS STUDENTS (0-2). Guest Lecturers. Review of experience tours. Thesis and research presentations. PREREQUISITE: None.

SM 0001 SEMINAR FOR SYSTEMS ACQUISITION MANAGEMENT STUDENTS (0-2). Guest Lecturers. Thesis and research presentations. PREREQUISITE: None.

CM 0810 THESIS RESEARCH FOR COMMUNICATIONS MANAGEMENT STUDENTS (0-0). Every student conducting thesis research will enroll in this course.

CT 0810 THESIS RESEARCH FOR COMPUTER SYSTEMS MANAGEMENT STUDENTS (0-0). Every student conducting thesis research will enroll in this course.

MN 0810 THESIS RESEARCH FOR MANAGEMENT STUDENTS (0-0). Every student conducting thesis research will enroll in this course.

OA 0810 THESIS RESEARCH FOR OPERATIONS RESEARCH/SYSTEMS ANALYSIS STUDENTS (0-0). Every student conducting thesis research will enroll in this course.

SM 0810 THESIS RESEARCH FOR SYSTEMS ACQUISITION MANAGEMENT STUDENTS (0-0). Every student conducting thesis research will enroll in this course.

Lower Division Courses

OS 1500 PERSONAL AFFAIRS (2-0). Personal estate planning including: government benefits, insurance, budgeting, real estate, securities, wills and trusts. PREREQUISITE: None.

Upper Division Courses

MN 2030 INTRODUCTION TO ECONOMICS (4-0). Survey of the methodology of economics and its application to such

problems as economic development, employment, inflation, industrial organization, consumer behavior and defense economics. PREREQUISITE: None.

MN 2035 SELECTED TOPICS IN ECONOMICS (2-0 to 5-0). Presentation of a wide selection of topics from the current literature. This course may be repeated for credit if course content changes. PREREQUISITE: A background in economics and Departmental approval.

MN 2510 HUMAN BEHAVIOR (4-0). A survey of some of the important aspects of human behavior that affect performance and satisfaction within an organization. Theories and empirical findings from the behavioral sciences, including motivation, learning, social conditioning, personality, and the measurement of individual behavior patterns. PREREQUISITE: None.

MN 2521 GROUP BEHAVIOR AND ORGANIZATION THEORY (4-0). A survey of theories and empirical findings concerning group effectiveness, leadership, group pressure, and role behavior. Theories and practices of organizational activities such as planning, direction, and control. Examination of organizational processes of particular importance to military and governmental organizations. PREREQUISITE: MN 2510.

MN 2525 SELECTED TOPICS IN BEHAVIORAL SCIENCES AND MANAGEMENT (2-0 to 5-0). Presentation of a wide selection of topics from the current literature. This course may be repeated for credit if course content changes. PREREQUISITE: A background in behavioral sciences and management and Departmental approval.

MN 2550 PRINCIPLES OF ACCOUNTING (4-0). Study of the basic principles of accounting in business and government. Topics covered include the basic postulates and principles of financial accounting, the accounting cycle, accounting for assets and equities, financial statement content and analysis, manufacturing cost accounting, and the fundamentals of governmetal accounting. PREREQUISITE: None.

MN 2555 SELECTED TOPICS IN ACCOUNTING AND FINANCIAL MANAGEMENT (2-0 to 5-0). Presentation of a wide selection of topics from the current literature. This course may be repeated for credit if course content changes. PREREQUISITE: A background in accounting and Departmental approval.

MN 2970 LOGISTICS MANAGEMENT (4-0). Military logistics processes and the organization of the Navy for logistics administration including: the planning-programming-budgeting cycle, budget development and execution, procurement, and hardware development. PREREQUISITE: None.

MN 2975 SELECTED TOPICS IN LOGISTICS AND PROCUREMENT (2-0 to 5-0). Presentation of a wide selection of topics from the current literature. This course may be repeated for credit if the course content changes. PREREQUISITE: A background in logistics and procurement and Departmental approval.

OA 2600 HISTORY AND NATURE OF OPERATIONS ANALYSIS (2-0). The origins of Operations Analysis in Britain are discussed and the relationship of Operations Research to fundamental and applied research is considered. The application of quantitative analysis and scientific methodology to military operations is introduced by the review of World War II studies of ASW and Air Warfare. PREREQUISITE: None.

OA 2601 INTRODUCTION TO DECISION ANALYSIS (2-0). This course provides an introduction to the vital role of models in operations research and systems analysis. The basic structure of decision problems is developed and interpreted in a variety of circumstances. The importance of inductive and deductive reasoning for model building is stressed. PREREQUISITE: None.

OA 2910 SELECTED TOPICS IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS (2-0 to 5-0). Presentation of a wide selection of topics from the current literature. This course may be repeated for credit if course content changes. PREREQUISITE: A background in operations research.

OS 2201 ELEMENTS OF OPERATIONS RESEARCH/SYSTEMS ANALYSIS (4-0). An introductory course. Topics covered include nature, origin, and contemporary status of operations analysis; problem formulation. PREREQUISITE: PS 2501 or equivalent.

Upper Division or Graduate Courses

MN 3043 ECONOMIC DEVELOPMENT (4-0). Goals and problems of economic development. Theoretical and policy issues, approaches to economic development, market system vs. public planning. PREREQUISITES: MN 3130, MN 3141 or MN 3140.

MN 3046 COMPARATIVE ECONOMIC SYSTEMS (4-0). The characteristics and funtions of an economic system. Criteria for evaluating the performance of contemporary economics. The analysis of alternative patterns of control, planning and market structures under capitalism, socialism, and mixed economics. PREREQUISITES: MN 3140 or MN 3141 and MN 3130.

MN 3105 THE THEORY AND PRACTICE OF MANAGEMENT (4-0). An introduction to the field of management as a body of knowledge related to a concrete practice. Discusses the various theories of management, their origins, their substance, and their applications to real world situations. PREREQUISITES: MN 3106, MN 3150, MN 3140 or MN 3141.

MN 3106 BEHAVIORAL SCIENCE (4-0). Aspects of individual and group behavior and their influence on organizational effectiveness. PREREQUISITE: None.

MN 3110 INDIVIDUAL BEHAVIOR (4-0). Study of the basic characteristics and determinants of individual behavior. Specific topics covered include personality, motivation, learning, behavior conditioning, and introduction to tests and measurements. Implications for effective administrative practice. PREREQUISITE: MN 3106.

MN 3121 GROUP AND ORGANIZATIONAL BEHAVIOR (4-0). Studies of small group behavior and the relationship between the individual and the group. Survey of organization theory, including organizational structure, controls and systems. Analysis of decision making processes in organizations, of leadership, of factors affecting organizational growth and development. PREREQUISITE: MN 3106.

MN 3125 ORGANIZATIONAL BEHAVIOR AND ADMINISTRATION (4-0). Analysis of human situations within organizations and their administrative implications. The course focuses on the responses made by individuals and groups to the influences bearing upon their behavior in organizational settings. PREREQUISITE: MN 3106.

MN 3126 SELECTED TOPICS IN BEHAVIORAL SCIENCES AND ADMINISTRATION (2-0 to 5-0). Presentation of a wide selection of topics from the current literature. This course may be repeated for credit if course content changes. PREREQUISITE: A background in behavioral sciences and management and Departmental approval.

MN 3130 MACROECONOMIC THEORY (4-0). Development of macroeconomic models to analyze the relationships between aggregate demand, debt and financial assets, rate of technical advance, and national income. The monetary system and international monetary relationships. PREREQUISITE: MN 2030 or equivalent.

MN 3135 SELECTED TOPICS IN ECONOMICS (2-0 to 5-0). Presentation of a wide selection of topics from the current

literature. This course may be repeated for credit if course content changes. PREREQUISITE: A background in economics and Departmental approval.

MN 3140 MICROECONOMIC THEORY (4-0). Determinants of the allocation of resources and the composition of output. Consumer choice theory. Partial equilibrium analysis of the significance of market structure. Introduction to welfare economics using quantitative techniques. PREREQUISITES: MN 2030 or equivalent; calculus.

MN 3141 MICROECONOMICS (4-0). Determinants of the allocation of resources and the composition of output. Consumer behavior and utility theory; theories of the firm; significance of market structure. PREREQUISITE: MN 2030 or equivalent.

MN 3142 INTERNATIONAL ECONOMICS (4-0). A study of international economic theory and international finance. Major topics include trade and resource allocation, the balance of payments, the foreign exchange market, and international economic equilibrium. Special emphasis on the relationship of DOD to international trade and finance. PREREQUISITES: MN 3140 or MN 3141, MN 3130.

MN 3143 MANAGERIAL ECONOMICS (4-0). Microeconomic theory and its applications and capital budgeting; significance of market structure upon performance, investment decisions and capital budgeting. Case and Industry studies. PREREQUISITE: MN 2030 or equivalent.

MN 3147 LABOR ECONOMICS (4-0). Development of the labor movement, its organizational structure, ideologies, policies and practices. Alternative theories of wage determination. Effects of unions on wages and the rate of technical change. PREREQUISITE: MN 3141 or MN 3140.

MN 3150 FINANCIAL ACCOUNTING (4-0). Study of the basic postulates and principles of accounting. Specific topics include the accounting cycle, asset valuation, equities and capital structure, financial statement analysis, and elementary cost accounting. PREREQUISITE: None.

MN 3161 MANAGERIAL ACCOUNTING (4-0). Survey of cost accounting systems, including overhead costing, job order and process cost systems, variable and absorption costing, and standard costs. Emphasis is on applications of accounting data to planning, control and decision making. Topics covered include flexible budgets, variance analysis, cost-volume-profit analysis, and incremental profit analysis. Capital budgeting is examined extensively. PREREQUISITE: MN 3150.

MN 3165 SELECTED TOPICS IN ACCOUNTING AND FINANCIAL MANAGEMENT (2-0 to 5-0). Presentation of a wide selection of topics from the current literature. This course may be repeated for credit if course content changes. PREREQUISITE: A background in accounting and financial management and Departmental approval.

MN 3170 DEFENSE RESOURCE ALLOCATION (4-0). Introduction to the management of resources within the Department of Defense, with particular emphasis on the economic, social, and political environment in which the military manager operates. Study of the problems of allocating resources for defense, providing support for military programs, and collecting and processing quantitative management information that relates to these resources. Specific topics include weapons systems acquisition, the planning-programming-budgeting cycle, research and development, material support, systems for management of resources for operating activities, systems for management of inventory and similar assets, and systems for management of acquisition, use, and disposition of capital assets. PREREQUISITES: MN 3211, MN 3150, MN 3140 or MN 3141.

MN 3183 MANAGEMENT USES OF COMPUTERS (4-0). Study of manual, semi-automatic, and automatic systems for the routine processing of data. Specific topics covered include accounting and auditing applications, sequential and random processing with digital computers, and control techniques. Students in small teams will study actual industrial and/or military management situations and recommend appropirate data processing systems. PREREQUISITES: CS 0110, PS 3000, MN 3105.

MN 3211 OPERATIONS ANALYSIS FOR MANAGEMENT I (3-2). Introduction to the philosophy and methodology of operations research. Survey of some of the more elementary techniques relating to decision making and optimization. PREREQUISITE: PS 3000.

MN 3212 OPERATIONS ANALYSIS FOR MANAGEMENT II (4-0). A continuation of MN 3211. Topics include: queueing, reliability, linear and dynamic programming, and gaming. PREREQUISITE: MN 3211.

MN 3213 INTRODUCTION TO LOGISTICS AND SUPPLY SYSTEMS (4-0). An introduction to logistic and supply management problems. Elements of inventory model building, allocation schemes. Emphasis on data source, collection, and reporting systems needed for management to operate supply systems economically. PREREQUISITE: MN 3211.

MN 3445 LINEAR ECONOMICS I (4-0). Development and application of linear models to the specification and control of economic relationships. Input-output models of the American economy; linear programming models of the firm; linear production functions and dynamic input-output models. PREREQUISITE: MN 3140 or MN 3141.

MN 3645 INVESTIGATIVE METHODS OF ECONOMICS I (4-0). Development and applications of selected statistical techniques. General linear hypothesis and regression theory. The Gauss-Markoff theorem; analysis of variance and hypothesis testing. Stochastic processes and their application. PREREQUISITES: MN 3140 or MN 3141, PS 3000.

MN 3770 INDUSTRIAL ORGANIZATION (4-0). Analysis of the structure, conduct and performance of American industry. Public policy issues, implementation of anti-trust and other business legislation. PREREQUISITES: MN 3140 or MN 3141, PS 3000.

MN 3780 ECONOMICS OF REGULATION (4-0). Analysis of regulatory alternatives and market performance in selected economic settings. Federal Government regulatory practice; communication; air; rail, and highway transportation; petroleum; product standardization; Armed Service Procurement Regulation. Applications of the public utility concept. State and local government practices. PREREQUISITE: MN 3140 or MN 3141.

MN 3950 WORKSHOP IN MANAGEMENT (2-0 to 5-0). This course may be repeated for credit if course content changes. PREREQUISITE: Departmental approval.

MN 3960 READINGS IN MANAGEMENT (2-0 to 5-0). This course may be repeated for credit if course content changes. PREREQUISITE: Departmental approval.

MN 3970 SEMINAR IN MANAGEMENT (2-0 to 5-0). Content of course varies. Students will be allowed credit for taking this course more than one time. PREREQUISITE: Departmental approval.

OA 3604 LINEAR PROGRAMMING (4-0). Theory of optimization of linear functions subject to linear constraints. The simplex algorithm, duality, dual simplex algorithm, sensitivity analysis, transportation algorithm, parametric linear programming, matrix payoff games, and integer linear programming. PREREQUISITE: MA 2042.

OA 3605 METHODS OF OPERATIONS RESEARCH/SYSTEMS ANALYSIS (4-0). A first course designed to survey the methodology of operations research and systems analysis. Topics in this sequence include: dynamic programming, PERT and PERT/COST, queueing, reliability, maintenance, replacement, networks, stochastic models, and allocation of search. PREREQUISITE: OA 3604.

OA 3609 INTRODUCTION TO MATHEMATICAL ECONOMICS (4-0). A study of consumer choice theory, producer choice theory, markets and general economic equilibrium. Basic welfare economics is also considered. PREREQUISITES: MA 2042, OA 3604 (or concurrently).

OA 3610 UTILITY THEORY AND RESOURCE ALLOCATION MODELS (4-0). The ature of individual preferences and their utility function representation in certain and risk environments. Introduction to utility functions (social welfare functions) for groups. The resource allocation problem of firms and economies interpreted as linear programming models. Introduction to non-linear resource allocation models. PREREQUISITES: OA 3609, OA 3604.

OA 3611 SYSTEMS ANALYSIS I (4-0). Principles of systems analysis and their relationship to the planning, programming, and budgeting system (PPBS), and the traditional OR models. Analysis of effectiveness measures and models. Cost estimating and analysis. Overall structure of cost-effectiveness and decision criteria. Risk and uncertainty problems. PREREQUISITES: OA 3604, OA 3610, OA 3303.

OA 3612 SYSTEMS ANALYSIS II (4-0). This course is to provide an integrated view of the nature of operations analysis. Projects are extensively used to permit the student a wide ranging final internship in the practice of operations research and systems analysis. PREREQUISITE: Open only to students in their final quarter of the Operations Research/Systems Analysis Master's Program.

OA 3620 INVENTORY I (4-0). A study of deterministic and approximate stochastic inventory models. Deterministic economic lot size models with infinite and finite production rate, constraints, quantity discounts. An approximate lot size-reorder point model with stochastic demand. An approximate stochastic "order up to R" model. Single period stochastic models. PREREQUISITES: MA 2110, OA 3302.

OA 3653 SYSTEM SIMULATION (4-0). Computer Simulation as a problem solving technique. Subject areas covered include: Monte Carlo methodology, simulation programming in FORTRAN, GPSS and other available simulation languages; and design of simulation experiments and analysis of results. PREREQUISITES: CS 0110 or equivalent, OA 3302.

OA 3654 WAR GAMING (3-2). Consideration of the problems inherent in the construction and use of manual and computer war games. Problems in the analysis of results of such games. PREREQUISITES: OA 3653, OA 3302.

OA 3656 OPERATIONS RESEARCH PROBLEMS IN SPECIAL WARFARE (4-0). The applicability of operations research to unconventional warfare and counterinsurgency. Normative and descriptive models. Consideration of special problems with emphasis on problem formulation. PREREQUISITES: OA 3604, OA 3303.

OA 3657 HUMAN FACTORS IN SYSTEMS DESIGN I (4-0). The human element in man-machine systems. Selected topics in human engineering and psychophysics with emphasis on their relation to military systems. PREREQUISITES: OA 3604, OA 3303.

OA 3658 HUMAN FACTORS IN SYSTEMS DESIGN II (3-0).. A continuation of OA 3657. Man-machine interface and man's motor and sensory capacities. PREREQUISITES: OA 3657 or Departmental approval.

OA 3660 ANALYSIS OF OPERATIONAL DATA (3-1). Analysis of real world operational data. The processing and interpretation of incomplete operational data. Problems will be chosen from current military problems. PREREQUISITES: OA 3303, OA 3653.

OA 3664 THEORY OF PATTERN RECOGNITION (3-0). Survey of principles governing the design of pattern recognition and detection devices of both the adaptive and nonadaptive types. Basic visual and auditory anatomy, along with the concepts and theories applicable to solving man's visual behavior problems in his role as a photo interpreter, radar operator, sonar operator or similar vigilance and tracking tasks. PREREQUISITE: OA 3303 or equivalent.

OA 3671 CYBERNETICS AND ANALYSIS OF INFORMATION SYSTEMS (4-0). Application of various OR/SA techniques to complex man-machine environments. Special emphasis upon the use of computer-based models in case study situations. Consideration of both data base problems and programmed decision-making. Attention to the problems which attend the implementation of such techniques as CPM and PERT. PREREQUISITES: OA 3611, OA 3654.

OA 3704 STOCHASTIC MODELS I (4-0). Markov chains. Basic concepts, transition probabilities, and classification characteristics of Markov chains, random walks, and branching processes. Applications to basic systems models and queues. PREREQUISITE: OA 3303.

OA 3900 WORKSHOP IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS (2-0 to 5-0). This course may be repeated for credit if course content changes. PREREQUISITE: Departmental approval.

OA 3910 SELECTED TOPICS IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS (2-0 to 5-0). Presentation of wide selection of topics from the current literature. This course may be repeated for credit if course content changes. PREREQUISITE: A background of advanced work in operations research.

OS 3201 FUNDAMENTALS OF OPERATIONS ANALYSIS (4-0). An introduction to quality assurance elements including design reliability assessment, production assessment testing, environmental testing, system reliability demonstration. Introduction to hardware performance measures. Introduction to cost effectiveness analysis. Elements of probability and statistics developed as needed. PREREQUISITE: Differential and integral calculus.

OS 3202 METHODS OF OPERATIONS ANALYSIS/SYSTEMS ANALYSIS (4-0). Methodology of operations analysis/systems analysis. Statistical estimation, and hypothesis testing. Life testing plans, point and interval estimates and reliability parameters. Elements and systems analysis pertaining to redundancy, maintainability, and spares. The role of systems analysis in solving military problems. PREREQUISITE: OS 3201 or equivalent.

OS 3203 SURVEY OF OPERATIONS ANALYSIS/SYSTEMS ANALYSIS (4-0). A survey of the military applications of operations analysis/systems analysis techniques of particular interest to the student. The applications usually covered are selected from decision, waiting lines, resource allocation, replacement, cost-effectiveness, inventory theory, and search models. The techniques needed for these applications are developed as required and usually include topics in linear programming (including the simplex method), probability theory, nonlinear programming, statistics (including Bayesian and classical), dynamic programming and simulation. PREREQUISITE: PS 3411 or equivalent.

OS 3204 DEFENSE RESOURCE ANALYSIS (4-0). The aim of this course is to present the nature, the aims, and limitations of analysis as it exists today and contributes to military problems. The common principles of cost/effectiveness analysis, design and formulation of the study, methods of solution, sensitivity analysis, pitfalls and limitations. Case studies from the field of interest of the class will be discussed. PREREQUISITE: PS 3411 or equivalent.

OS 3205 OPERATIONS RESEARCH FOR COMPUTER SCIENTISTS (4-0). An introduction to the methodology and techniques of operations research, with special emphasis on the computational aspects and on computer-related applications. Topics include linear programming, queueing theory, and PERT. Homework assignments include writing computer programs for some of the algorithms presented. PREREQUISITES: MA 2045, PS 3326, and CS 0110.

OS 3659 HUMAN FACTORS ENGINEERING FOR STUDENTS NOT IN OPERATIONS ANALYSIS (3-0). An introduction to human factors engineering for students in other fields such as engineering. Designed to give the student an appreciation of man's capacities and limitations and how these can effect the optimum design of the man-machine system. Emphasis on integration of human factors into the system development cycle considering such topics as manpower/personnel costs, control and display design, human energy expenditure, physiological costs, and evaluation systems. PREREQUISITE: A previous course in probability and statistics.

OS 3941 ENGINEERING ECONOMICS (4-0). An introduction to the basic concepts of microeconomics necessary for decision making; alternative market models; theories of production, with particular attention to technological considerations, production and cost functions; and supply curves. The analysis of investment decision problems. PREREQUISITE: None.

SM 3301 INTRODUCTION TO SYSTEMS ACQUISITION (4-0). This course provides students with an overview of the Systems Acquisition process, its underlying philosophies and concepts, its application in the Department of Defense and the Navy, and establishes the foundations for other courses in the curriculum. Topics covered include the evolution of systems acquisition management, the systems approach, the system life cycle and defense system acquisition cycle, user-producer acquisition management disciplines and activities. PREREQUISITE: None.

SM 3302 FUNDAMENTALS OF PROJECT MANAGEMENT (4-0). Study of the principles of management as a body of knowledge related to practice. Discusses the functions of management planning, organizing, staffing, directing, and controlling — as they apply within industry and government. Specific application of these principles and functions to project management are investigated. PREREQUISITE: None.

SM 3304 THE BEHAVIORAL SCIENCES AND PROJECT MANAGEMENT (4-0). Study of the field of behavioral science as a body of knowledge related to a concrete practice. Discusses the functions of management as they apply to the achievement of purposes by individuals and groups within an industrial or government organization. Examines various aspects of individual and group behavior and their influence on organizational effectiveness. Specific concepts include traditional and contemporary management theory; individual and group dynamics, motivation and control in the organization setting. PREREQUISITE: SM 3302.

SM 3305 PROJECT INFORMATION SYSTEMS (4-0). The course provides a fundamental grounding in computer operations. Material covered includes hardware and software systems, a survey of the various higher level programming languages, examples of computer systems applications, and the concepts of design of management information systems. Particular attention is paid to project management systems. PREREQUISITES: CS 0110, SM 3301, SM 3302.

Graduate Courses

CT 4182 DATA PROCESSING MANAGEMENT (4-0). Study of computer systems analysis and design. Management of ADP in the Federal Government, especially in the Department of Defense. Specific topics covered include: feasibility studies, selection, and acquisition of equipment; evaluation of computer hardware and software; installation and effective utilization of ADP equipment; and various types of computer applications. PREREQUISITE: CS 2100 or equivalent.

MN 4043 ECONOMIC DEVELOPMENT II (4-0). Theories of economic development, and development policy issues, country and regional studies. PREREQUISITES: MN 3043, MN 3130, and MN 3141 or MN 3140.

MN 4101 PERSONNEL MANAGEMENT AND LABOR RELATIONS (4-0). Study of the principles and practices of personnel administration in business and government organizations. A survey of the history, development and current status of labor-management relations in industry and government. Analysis of the economics of the labor market and the implications of government regulations for wages and labor-management bargaining practices. PREREQUISITES: MN 3106 and MN 3141 or MN 3140.

MN 4105 MANAGEMENT POLICY (4-0). Study and appraisal of a variety of policies requiring the analysis of problems and the formulation of decisions in both business and governmental enterprises. Use of case material, management games, and other devices as exercises in decision making and the executive action under conditions of uncertainty and change. PREREQUISITE: Open only to students in their final quarter of the Management Masters Program.

MN 4111 SEMINAR IN BEHAVIORAL SCIENCE (4-0). A combination of directed readings and individual student's research projects presented for discussion in class. Emphasis is placed on empirical analysis of behavioral patterns and relationships. PREREQUISITE: Departmental approval.

MN 4112 PERSONNEL SELECTION AND CLASSIFICATION (4-0). Analysis of human performance within organizations. This course considers the methods available for measuring and predicting the performances of the members of organizations. Methods of measuring differences between people via employment interviewing, testing, and life-history data are discussed. Techniques for studying and recording job behavior are also considered. In addition, the various strategies for personnel decisions are discussed in terms of validation, and selection and placement models. PREREQUISITES: MN 3110 and PS 3000.

MN 4113 PERSONNEL TRAINING AND DEVELOPMENT (4-0). Determination of the skills, knowledges and attitudes in which people should be trained. Analysis of who should be trained and the methods currently available for training are discussed. Techniques available for evaluating the efficiency of training are also considered. PREREQUISITES: MN 3110, PS 3000 (may be taken concurrently).

MN 4114 PERSONNEL PERFORMANCE EVALUATION (4-0). Current methods of appraising the work performance of individuals in different types of work are reviewed. Problems associated with each method are analyzed. Performance evaluation is examined as a system interfacing with selection, classification, training, advancement, and retention. PREREQUISITES: MN 3106 and PS 3000.

MN 4115 PERSONNEL MOTIVATION (4-0). A brief summary of the traditional theories of motivation is given. Several motivation to work theories are discussed along with the research concerning these theories. Current research on the roles of compensation in personnel motivation is considered. PREREQUISITE: MN 3110.

MN 4121 SEMINAR IN ORGANIZATION THEORY AND MANAGEMENT PRACTICE (4-0). A research and discussion approach to the problem areas of organization theory, management practice, and the contributions of various theoretical disciplines to the evolving sciences of management. Particular attention is given to the implications of changes in the environment of organizations, in their internal technology, and in the state of knowledge about human behavior. PREREQUISITE: Departmental approval.

MN 4126 SELECTED TOPICS IN BEHAVIORAL SCIENCES AND ADMINISTRATION (2-0 to 5-0). Presentation of a wide selection of topics from the current literature. This course may be repeated for credit if course content changes. PREREQUISITE: A background in behavioral sciences and management and Departmental approval.

MN 4130 MACROECONOMIC POLICY (4-0). Development and application of aggregate economic models to selected policy issues. Emphasis will be placed upon the use and interpretation of econometric models. PREREQUISITES: MN 3130, and MN 3141 or MN 3140.

MN 4133 ECONOMICS OF COMPUTERS (4-0). Analytical tools of microeconomics and statistics applied to decision making in computer management. Economics issues and legal constraints related to computer hardware and software systems are discussed. PREREQUISITES: MN 3140 or MN 3141, PS 3000 and Departmental approval.

MN 4135 MONETARY ECONOMICS (4-0). The interrelations between monetary and non-monetry variables in the economy. PREREQUISITES: MN 3130, and MN 3140 or MN 3141.

MN 4141 ECONOMIC THEORY AND MICROECONOMIC POLICY (4-0). Further developments of the concepts of imperfect competition and economic efficiency. Pricing and price-making policy issues. Introduction to economics of risk aversion. Analyses of major U.S. industries and government policies. PREREQUISITES: MN 3130, and MN 3140 or MN 3141.

MN 4142 INTERNATIONAL ECONOMIC POLICY (4-0). Leading issues of international trade policy. Emphasis on the relation of theory to specific international problems. Analysis of commercial policies of the U.S., European economic unions and developing countries. PREREQUISITES: MN 3140 or MN 3141, MN 3130, MN 3142.

MN 4145 SYSTEMS ANALYSIS (4-0). This course will concentrate on the analysis of large scale defense resource allocation problems, using cost-effectiveness models. Topics include: discounting, constrained optimization, estimation problems, and efficiency over time. Systems analysis case studies will be emphasized. PREREQUISITES: MN 3150, MN 3141 or MN 3140, MN 3161 (concurrently), PS 3000 (concurrently).

MN 4146 SELECTED TOPICS IN SYSTEMS ANALYSIS AND DEFENSE RESOURCE ALLOCATION (2-0 to 5-0). Presentation of a wide selection of topics from the current literature. This course may be repeated for credit if course content changes. PREREQUISITE: A background of advanced work in systems analysis and resource management and Departmental approval.

MN 4147 INDUSTRIAL RELATIONS (4-0). Development of the institutions and techniques for resolving conflict over wages and conditions of work. Theories of bargaining and arbitration. PREREQUISITE: MN 3147.

MN 4148 SELECTED TOPICS IN PERSONNEL MANAGEMENT AND INDUSTRIAL RELATIONS (2-0 to 5-0). Presentation of a wide selection of topics from the current literature. This course may be repeated for credit if course content changes. PREREQUISITE: A background of advanced work in personnel management and industrial relations and Departmental approval.

MN 4151 INTERNAL CONTROL AND AUDITING (4-0). Study of the objectives and procedures of internal control in government and industry. Examination of the independent audit function, including auditing standards and reports. Study of internal auditing, with emphasis on operational audits. Consideration of the principal Federal audit organizations. Specialized topics including sampling techniques for auditing, audits of computer-based systems, and audit problems associated with selected assets and operations. PREREQUISITES: MN 3150, MN 3161 and PS 3000.

MN 4152 DECISION MAKING FOR FINANCIAL MANAGEMENT (4-0). The management of the finance function in government and industry. Specific topics include cash and working capital management, long-term financing, determination of optimal capital structure, and valuation of a going concern. PREREQUISITES: MN 3161 and PS 3000.

MN 4153 SEMINAR IN ACCOUNTING AND CONTROL (4-0). Research and discussion of current developments and controversies in accounting and financial controls for government and industry. Students will be expected to do individual or small-group studies and to make reports thereon. PREREQUISITES: MN 3161, CS 0110, and PS 3000 or equivalent.

MN 4154 SEMINAR IN FINANCIAL MANAGEMENT (4-0). Study of the theories of and applications in the administration and allocation of financial resources. PREREQUISITES: MN 3161, MN 3211, MN 3140 or MN 3141.

MN 4161 CONTROLLERSHIP (4-0). This course employs the case method of study and seeks to integrate the various disciplines that support the management function, with particular emphasis on financial analysis for decision making. PREREQUISITES: MN 3121, MN 3161, CS 0110, and MN 3211.

MN 4165 SELECTED TOPICS IN ACCOUNTING AND FINANCIAL MANAGEMENT (2-0 to 5-0). Presentation of a wide selection of topics from the current literature. This course may be repeated for credit if course content changes. PREREQUISITE: A background of advanced work in accounting and financial management and Departmental approval.

MN 4171 PROCUREMENT AND CONTRACT ADMINISTRATION (4-0). Study of the elements of the procurement cycle, including the determination of the requirements, contract law, technical and production problems, fiscal controls, facilities, inspections, and terminations. Military procurement regulations are analyzed to determine their impact on efficient military logistic systems. PREREQUISITE: MN 3161, MN 4145.

MN 4172 MARKETING STRATEGY (4-0). Research and study of areas of marketing that are applicable to management strategy. Typical areas to be considered are: sensitivity to the environment; value of analytical tools; behavioral considerations; creativity and innovative approaches; marketing research as a tool; influence of Federal statutes. PREREQUISITES: MN 3211.

MN 4174 TRANSPORTATION MANAGEMENT (4-0). Provides a fundamental knowledge of problems and practices encountered in the management of transportation systems. Areas covered include an economic analysis of a study of present and future trends in commercial transportation. This course will focus on the importance of coordinated transportation management in large-scale systems. PREREQUISITES: MN 3211, MN 3161, MN 4145.

MN 4175 RHOCHREMATICS (4-0). Study of the science of managing material flow, embracing the basic functions of pro-

ducing and marketing as an integrated system and involving the selection of the most effective combination of subfunctions such as transporting, processing, handling, storing, and distributing goods. PREREQUISITES: MN 3211, MN 3161, MN 4145.

MN 4176 SELECTED TOPICS IN LOGISTICS AND PROCUREMENT (2-0 to 5-0). Presentation of a wide selection of topics from the current literature. This course may be repeated for credit if course content changes. PREREQUISITE: A background of advanced work in logistics and procurement and Departmental approval.

MN 4181 MANAGEMENT INFORMATION SYSTEMS (4-0). Study of the "total systems" concept. Development and discussion of an integrated information system, employing a computer and data processing equipment, used by management for planning and control purposes. Analysis of actual information systems used in industry and the government. PREREQUISITES: MN 3150, MN 3183 and CS 0110.

MN 4185 SELECTED TOPICS IN INFORMATION SYSTEMS (2-0 to 5-0). Presentation of a wide selection of topics from the current literature. This course may be repeated for credit if course content changes. PREREQUISITE: A background of advanced work in information systems and Departmental approval.

MN 4191 QUANTITATIVE DECISION TECHNIQUES (4-0). A study of the applications of scientific techniques, particularly mathematical and statistical, to management decision making. Consideration of application of quantitative methods of analysis to complex problems with the aid of computers. PREREQUISITES: CS 0110, MN 3211, and MN 3212.

MN 4225 LABOR LAW (4-0). Labor Law as it affects management, labor and the public with special emphasis on legal problems confronting military personnel in managerial situations. PREREQUISITE: MN 4101.

MN 4445 LINEAR ECONOMICS II (4-0). Linear models of multi-stage decision making. Dynamic programming; alternative approaches to multi-dimensional optimization problems. PREREQUISITE: MN 3445.

MN 4645 INVESTIGATIVE METHODS OF ECONOMICS II (4-0). Specification of economic systems. Simultaneous equations and identification issues in econometric model construction. Application of econometric methods in analyses of industrial organization and economic planning. PREREQUISITE: MN 3465.

MN 4931 MACROECONOMIC THEORY (4-0). Advanced study in such areas as national income accounting, aggregate demand relationships, aggregate production functions and aggregate supply relationships. Theory of aggregation considered. PREREQUISITE: MN 3130 and Departmental approval.

MN 4941 MICROECONOMIC THEORY (4-0). Advanced study in such areas as consumer choice, producer choice, market structure, partial and general economic equilibrium. Some consideration of economic dynamisc. PREREQUISITES: MN 3140 or MN 3141, and Departmental approval.

MN 4945 SELECTED TOPICS IN ECONOMICS (2-0 to 5-0). Presentation of a wide selection of topics from the current literature. This course may be repeated for credit if course content changes. PREREQUISITE: A background of advanced work in economics and Departmental approval.

MN 4950 WORKSHOP IN MANAGEMENT (2-0 to 5-0). This course may be repeated for credit if course content changes. PREREQUISITE: Departmental approval.

MN 4960 READINGS IN MANAGEMENT (2-0 to 5-0). This course may be repeated for credit if course content changes. PREREQUISITE: Departmental approval.

MN 4970 SEMINAR IN MANAGEMENT (2-0 to 5-0). Content of course varies. Students will be allowed credit for taking this course more than one time. PREREQUISITE: Departmental approval.

OA 4613 THEORY OF SYSTEMS ANALYSIS (4-0). Systems analysis (cost-effectiveness analysis) formulated as commensurable and incommensurable physical capital investment choice models. Emphasis on decision rules and the nature of opportunity costs with respect to scale and timing of investment. Interpretation of methods of risk modeling and solution computation. Theory of the second best; theory of the social discount rate. Introduction to models of planning and control emphasizing decentralization of the decision-making problem. PREREQUISITES: OA 3611, OA 4631 (or concurrently).

OA 4614 METHODS AND PRACTICE OF SYSTEMS ANALYSIS (4-0). Advanced study in the methods and practice of systems analysis with emphasis on cost analysis; cost models and methods for total program structures and single projects; relationship of effectiveness models and measures to cost analyses; public capital budgeting of interrelated projects; detailed examples from current federal practices. PREREQUISITE: OA 3611.

OA 4615 ECONOMETRICS (4-0). An introduction to the construction of testing of econometric models, analysis of economic time series, and the use of multivariate statistical analysis in the study of economic behavior. PREREQUISITES: OA 3303, OA 3610.

OA 4621 INVENTORY II (4-0). A study of stochastic inventory models. Single period models with time dependent costs, constrained multiple item single period models, deterministic and stochastic dynamic inventory models, the (r,R) periodic review model, the Q = 1 continuous review model, demand forecasting. PREREQUISITES: OA 3604, OA 3620.

OA 4622 SEMINAR IN SUPPLY SYSTEMS (4-0). A survey of supply systems, not only from an inventory point of view, but also as a critical area in logistics. Topics for discussion will be selected from the current literature and will be chosen according to students interests. Periodically, experts in the supply field will provide guest lectures on current research areas. PREREQUISITES: OA 4621, OA 3704, or Departmental approval.

OA 4631 NONLINEAR AND DYNAMIC PROGRAMMING (4-0). Introduction to modern optimization techniques and multistage decision processes. Topics include: Kuhn-Tucker theory, quadratic programming, stochastic programming, chance-constrained programming, gradient and search methods, and dynamic programming. PREREQUISITES: OA 3604, MA 2110.

OA 4632 MATHEMATICAL PROGRAMMING (4-0). The bounded variable algorithm, decomposition principle, primal-dual algorithm. Special topics such as linear fractional programming, stochastic programming, chance-constrained linear programming, theory of degeneracy procedures, and the generalized transportation problem. Applications: PERT and PERT/COST, warehouse problem, caterer problem, assignment problems, overtime production, etc. PREREQUISITE: OA 3604.

OA 4633 NETWORKS FLOWS AND GRAPHS (4-0). Survey of solution techniques for problems which can be related to problems involving flows in networks. Elements of graph theory, max-flow min-cut theorem, shortest route problems, minimal cost flows, out-of-kilter algorithm, CPM, PERT/Cost, and PERT/Time. PREREQUISITE: OA 3604.

OA 4634 GAMES OF STRATEGY (4-0). Games as mathematical models of conflict situations. Fundamental concepts: objective and subjective basis. The canonical, dynamic, and characteristic function forms. Zero-sum, n-person noncooperative and multistage games. Coalitions and cooperative games with and without side payments. Postulates of rational behavior, dominance, and stability. Valuation and bargaining models. PREREQUISITE: OA 3610.

OA 4635 NONLINEAR PROGRAMMING (4-0). Continuation of OA 4631. Fritz John Theory. Complimentary pivot theory. Beal's method. Approximate methods. Further results in gradient and search methods. Duality in non-linear programming. Optimal control problems. PREREQUISITE: OA 4631.

OA 4636 DYNAMIC PROGRAMMING (4-0). A continuation of OA 4631. Basic theory of Dynamic Programming with applications. Recursive equations, computational methods and refinements, stochastic and adaptive decision making and infinite stage systems are discussed. PREREQUISITE: OA 4631.

OA 4638 VARIATIONAL METHODS OF OPTIMIZATION (4-0). Optimization of dynamic systems including systems with one or two controllers, one or two criterion functions, and perfect or imperfect information. Optimization techniques will include: classical calculus of variations, Caratheodory's approaches, dynamic programming, and differential games. Applications will be made to inventory theory, tactical allocation problems, search, pursuit, evasion, and surveillance. PREREQUISITE: OA 4631 or OA 4654 or equivalent.

OA 4642 ADVANCED TOPICS IN WAR GAMING AND SIMULATION (3-2). A greater-depth coverage of material introduced in OA 3653 and OA 3654. Advanced techniques of model development and simulation experimentation. Discussion of current research. Actual topics selected will depend on interests of students and instructor. This course is particularly appropriate for those doing theses in this area. PREREQUISITE: OA 3654 and Departmental approval.

OA 4651 SEARCH THEORY AND DETECTION (4-0). Search and detection as stochastic processes. Characterization of detection devices, use and interpretation of sweep widths, lateral range curves, true range curves. Measures of effectiveness of search-detection systems. Allocation of search effort, sequential search. Introduction to the statistical theory of signal detection. Models of surveillance fields, barriers, tracking, and trailing. PREREQUISITE: OA 3303 or equivalent.

OA 4652 OPERATIONS RESEARCH PROBLEMS IN NAVAL WARFARE (3-0). Analyses of fleet exercises. Changes in tactics and force disposition arising from the introduction of nuclear weapons and missiles. Relationship of air defense to strike capability and ASW. Current radar, sonar, communication, and ECM problems. PREREQUISITE: OA 4651.

OA 4654 MATHEMATICAL MODELS OF COMBAT (4-0). Survey of mathematical models of combat processes. Models of interest will include Target acquisition, tactical allocation models of two-sided dynamic situations, coverage models, theory of duels, Lanchester theory of combat, and stochastic combat processes. Introduction to the optimization of combat dynamics using dynamic programming, optimal control theory, and differential games. PREREQUISITE: OA 3704 or equivalent.

OA 4655 OPTIMIZATION OF COMBAT DYNAMICS (4-0). Study of the optimization of combat dynamics using dynamic programming and optimal control theory combined with the Lanchester theory of combat. Allocation of effort in search theory, distribution of gunfire, selection of aim point distribution. Advanced topics in stochastic combat processes (surveillance of region, Lanchester attrition-rate distribution) and Lanchester theories (range/time dependent attrition rates). Strategy in a missile war: targets and rates of fire. PREREQUISITE: OA 4654.

OA 4662 RELIABILITY AND WEAPONS SYSTEM EFFECTIVENESS MEASUREMENT (4-0). Component and System reliability functions and their point and interval estimates under various sampling plans. Review of selected MILSTD reliability of documents and the WSEIAC reports. Reliability and System effectiveness measurement and analysis of the Fleet Ballistic Missile Weapon System and other selected Weapons systems. Measurement indices for Weapons System Effectiveness. PREREQUISITE: OA 4705 (may be taken concurrently) or equivalent.

OA 4673 UTILITY THEORY (3-0). General concept of utility and its measurement. Survey and critique of the current literature dealing with the concept and measurement of utility. Applications to problems of human relations. PREREQUISITE: OA 3610.

OA 4680 HUMAN PERFORMANCE EVALUATION (4-0). Experimental considerations, strategy, and techniques in evaluation of human performance characteristics and capabilities. Detailed examination of special methods to include multivariate designs, psychophysical methods, and psychophysiological methods. Review of important variables affecting human performance and criteria, measures of effectiveness, and figures of merit as indicants of performance quality. PREREQUISITE: OA 3657.

OA 4705 STOCHASTIC MODELS II (4-0). Poisson processes. Renewal theory and semi-Markov processes. Stochastic models of complex military systems and applications in economics, communications and inventory models. Maintenance policies. PREREQUISITE: OA 3704.

OA 4706 STOCHASTIC MODELS III (4-0). The course will cover selected topics in queueing theory relevant to applications. Included will be deterministic queues, priority queueing systems with applications such as cm computer time sharing, inequalities and approximations for general single served queues, multi-channel and tandom queue approximations, and heavy traffic queues with applications of the diffusion process. PREREQUISITE: OA 4705.

OA 4900 WORKSHOP IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS (2-0 to 5-0). This course may be repeated for credit if course content changes. PREREQUISITE: Departmental approval.

OA 4910 SELECTED TOPICS IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS (2-0 to 5-0). Presentation of a wide selection of topics from the current literature. This course may be repeated for credit if course content changes. PREREQUISITE: A background of advanced work in operations research and Departmental approval.

OA 4930 READINGS IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS (2-0 to 5-0). This course may be repeated for credit if course content changes. PREREQUISITE: Departmental approval.

OA 4940 SEMINAR IN OPERATIONS RESEARCH/SYSTEMS ANALYSIS (2-0 to 5-0). Content of course varies. Students will be allowed credit for taking the course more than one time. PREREQUISITE: Departmental approval.

SM 4301 SYSTEMS ENGINEERING MANAGEMENT (4-0). This course covers technical management as applied to the Systems Acquisition process. It emphasizes the life cycle integration of the various systems engineering disciplines. Topics include systems engineering, the system life cycle and system design process, systems engineering disciplines and their integration, systems engineering management during concept formulation, system definition, full scale development, production and deployment. PREREQUISITES: SM 3301, SM 3302, OA 4662.

SM 4302 PUBLIC EXPENDITURE, POLICY AND ANALYSIS (4-0). The process of national decision-making particularly as reflected in the defense budgeting process. Models of budget decision making, including decentralization. Application of social choice concepts. Applications from the defense budgeting process. PREREQUISITES: MN 3161, MN 4145.

SM 4303 PROCUREMENT PLANNING & NEGOTIATION (4-0). Study of the procurement planning and negotiation phases of the procurement cycle, including the determination of

need, basic contract law, methods of procurement, fundamentals of the Armed Services Procurement Regulations and current procurement management techniques. PREREQUISITES: SM 3301, SM 4301 (concurrently).

SM 4304 CONTRACT ADMINISTRATION (4-0). Study of defense procurement contract administration, managing contract progress, change control, cost control, sub-contracting regulations and administration, product acceptance and contract termination. PREREQUISITE: SM 4303.

SM 4305 LOGISTIC SUPPORT (4-0). This course defines and describes the major fields of logistic support and introduces various models of logistical areas. These areas of support include: personnel, consumables, facilities, material transportation and maintenance. The field of integrated logistics support is introduced along with trade-offs between types of support in optimizing support systems. Data bases and techniques for determination of support requirements are treated briefly. PREREQUISITE: SM 4301.

PROBABILITY AND STATISTICS

Upper Division Courses

*PS 2000 ELEMENTARY PROBABILITY AND STATISTICS (4-0).

OA 2301 PROBABILITY (4-0). Axiomatic development of probability and its use in model building. Random variables and their probability distributions. Moments and other characteristics of probability laws and their importance in formulating and solving operations analysis problems. Jointly distributed random variables and their use in defining behavior of complex systems. PREREQUISITE: A previous course in differential and integral calculus.

*PS 2315 DATA REDUCTION AND ERROR ANALYSIS (4-0).

*PS 2501 INTRODUCTION TO PROBABILITY AND STATISTICS (4-0).

Upper Division or Graduate Courses

*PS 3000 MANAGEMENT STATISTICS (5-0).

*PS 3011 PROBABILITY AND STATISTICS FOR MANAGEMENT I (4-0).

*PS 3012 PROBABILITY AND STATISTICS FOR MANAGEMENT II (4-0).

OA 3302 PROBABILITY AND STATISTICS (4-1). Independence and conditional distributions. Stochastic inequalities, analysis/systems analysis. Derived distributions of functions of approximations, and limit properties, and their use in operations random variables. Random sampling and distribution of sampling statistics with application to model building and Bayesian techniques. PREREQUISITE: OA 2301.

OA 3303 STATISTICS (4-1). Confidence interval estimation and hypothesis testing. Regression and correlation analysis. Elements of the analysis of variance. Nonparametric inference. Applications to reliability, quality assurance, and operations analysis problems. PREREQUISITE: OA 3302.

*PS 3401 INTERMEDIATE PROBABILITY AND STATISTICS I (4-0).

*PS 3402 INTERMEDIATE PROBABILITY AND STATISTICS II (4-0).

*PS 3411 APPLIED PROBABILITY THEORY I (4-1).

*PS 3412 APPLIED PROBABILITY THEORY II (4-0).

*PS 3421 NONPARAMETRIC STATISTICS (4-0).

*PS 3441 ANALYSIS OF VARIANCE AND DESIGN OF EXPERIMENTS (4-0).

OA 3510 SELECTED TOPICS IN PROBABILITY AND STATISTICS (2-0 to 5-0). Topics will be selected by instructor to fit the needs and background of the students. The topics may include advanced probability, sampling inspection, quality assurance, nonparametric methods, and sequential analysis. The course may be repeated for credit if the topic changes. PREREQUISITE: OA 3303 or Departmental approval.

Graduate Courses

*PS 4001 ADVANCED PROBABILITY THEORY (3-0).

*PS 4002 ADVANCED STATISTICS AND DECISION THEORY (3-0).

OA 4306 APPLIED STATISTICS (4-0). Multivariate analysis with applications. Multiple comparisons. Bayesian and classical classification models. Outliers. Use of digital computer in multivariate problems. PREREQUISITE: OA 3303.

OA 4321 DESIGN OF EXPERIMENTS (3-1). Theory of the general linear hypotheses. Analysis of variance. Planning of experiments. Randomized block and Latin squares. Simple factorial experiments. PREREQUISITE: OA 3303.

OA 4322 SAMPLE INSPECTION AND QUALITY ASSURANCE (3-1). Attribute and variables sampling plans. MIL. STD. sampling plans with modifications. Multi-level continuous sampling plans and sequential sampling plans. Structure of quality assurance programs and analysis of selected quality assurance problems. PREREQUISITE: OA 3303.

OA 4323 DECISION THEORY (3-0). Basic concepts. Bayes, admissible, minimax, and regret strategies. Principles of choice. Relation of statistical decision functions to the theory of games. Applications in the planning of operational evaluations trials. PREREQUISITE: OA 3303.

*PS 4325 ADVANCED DESIGN OF EXPERIMENTS (4-0).
OA 4431 ADVANCED PROBABILITY (3-0). Convergence almost surely, in probability and in quadratic mean. Distribution function and characteristic functions. Infinitely divisible laws. Strong and weak laws of large numbers. Classical central limit problems, moder central limit problems. PREREQUISITE: MA 3606, MA 3172, and Departmental approval.

OA 4432 STOCHASTIC PROCESSES I (4-0). The Kolmogorov Theorem. Analytic properties of sample functions. Continuity and differentiability in quadratic mean. Stochastic integrals. Stationary processes. PREREQUISITE: OA 4431.

OA 4433 STOCHASTIC PROCESSES II (4-0). Continuation of OA 4432. Stationary and non-stationary normal processes. Diffusion and random walks. Crossing problems. Martingale, limit theorems and the invariance principle. PREREQUISITE: OA 4432.

OA 4440 TIME SERIES ANALYSIS (4-0). Second order stationary processes. Harmonic analysis of correlation functions. Filters and spectral windows. Ergotic properties. Problems of inference in time series analysis. Introduction to the analysis of multivariate processes. Course should be taken concurrently with OA 4432.

OA 4510 SELECTED TOPICS IN PROBABILITY AND STATISTICS (2-0 to 5-0). Topics will be selected by instructor to fit the needs and background of the students. The topics may include advanced probability, sampling inspection, quality assurance, nonparametric methods, and sequential analysis. The course may be repeated for credit if the topic changes. PREREQUISITE: OA 3303 or Departmental approval.

**See listing under Mathematics Department.*

DEPARTMENT OF PHYSICS

Otto Heinz, Professor of Physics; Chairman (1962)*; B.A., Univ. of California at Berkeley, 1948; Ph.D., 1954.

Robert Louis Armstead, Associate Professor of Physics (1964); B.S., Univ. of Rochester, 1958; Ph.D., Univ. of Caliornia at Berkeley, 1964.

Fred Ramon Buskirk, Associate Professor of Physics (1960); B.S., Western Reserve Univ., 1951; Ph.D., Case Institute of Technology,, 1958.

Natale Mauro Ceglio, Lieutenant, U. S. Naval Reserve; Instructor in Physics (1969); B.S., Columbia Univ., 1967; M.S., Massachusetts Institute of Technology, 1969.

Alfred William Madison Cooper, Associate Professor of Physics (1957); B.A., Univ. of Dublin, 1955; M.A., 1959; Ph.D., The Queen's University of Belfast, 1961.

John Niessink Cooper, Professor of Physics (1956); B.A., Kalamazoo College, 1935; Ph.D., Cornell Univ., 1940.

Alan Berchard Coppens, Associate Professor of Physics (1964); B.Eng.Phy., Cornell Univ., 1959; M.S., Brown Univ., 1962; Ph.D., 1965.

Eugene Casson Crittenden, Jr., Distinguished Professor of Physics (1953); B.A., Cornell Univ., 1934; Ph.D., 1938.

Harvey Arnold Dahl, Assistant Professor of Physics (1964); B.S., Stanford Univ., 1951; Ph.D., 1963.

Edgar Brandon Dally, Associate Professor of Physics (1970); B.A., Miami Univ., 1953; M.S., 1955; Ph.D., Stanford Univ., 1961.

John Norvell Dyer, Professor of Physics (1961); B.A., Univ. of California at Berkeley, 1956; Ph.D., 1960.

Anthony Irving Eller, Assistant Professor of Physics (1969); A.B., Harvard Univ., 1960; M.S., Univ. of Rochester, 1963; Ph.D., 1966.

Garrett Aquila Garrettson, Lieutenant, U. S. Navy; Assistant Professor of Physics (1969); M.S., Stanford Univ. 1966; Ph.D., 1969.

Harry Elias Handler, Professor of Physics (1958); B.A., Univ. of California at Los Angeles, 1949; M.A., 1951; Ph.D., 1955.

Don Edward Harrison, Jr., Professor of Physics (1961); B.S., College of William and ,Mary 1949; M.S., Yale Univ., 1950; Ph.D., 1953.

Sydney Hobart Kalmbach, Professor of Physics (1947); B.S., Marquette Univ., 1934; M.S., 1937.

Raymond Leroy Kelly, Professor of Physics (1960); B.A., Univ. of Wichita, 1947; M.S., Univ. of Wisconsin, 1949; Ph.D., 1951.

Xavier Kuniteru Maruyama, Lieutenant, U. S. Navy; Assistant Professor of Physics (1971); B.S., Univ. of Notre Dame, 1966; Ph.D., Massachusetts Institute of Technology, 1971.

Herman Medwin, Professor of Physics (1955); B.S., Worcester Polytechnic Institute, 1941; M.S., Univ. of California at Los Angeles, 1948; Ph.D., 1953.

Edmund Alexander Milne, Associate Professor of Physics (1954); B.A., Oregon State College, 1949; M.S., California Institute of Technology, 1950; Ph.D., 1953.

John Robert Neighbours, Professor of Physics (1959); B.S., Case Institute of Technology, 1949; M.S., 1951; Ph.D., 1953.

Leonard Oliver Olsen, Professor of Physics (1960); B.A., Iowa State Teachers College, 1932; M.S., State Univ. of Iowa, 1934; Ph.D., 1937.

William Reese, Associate Professor of Physics (1963); B.A., Reed College, 1958; M.S., Univ. of Illinois, 1960; Ph.D., 1962.

John Dewitt Riggin, Professor of Physics (1946); B.S., Univ. of Mississippi, 1934; M.S., 1936.

George Wayne Rodeback, Associate Professor of Physics (1960); B.S., Univ. of Idaho, 1943; M.S., Univ. of Illinois, 1947; Ph.D., 1951.

James Vincent Sanders, Associate Professor of Physics (1961); B.S., Kent State Univ., 1954; Ph.D., Cornell Univ. 1961.

Gordon Everett Schacher, Associate Professor of Physics (1964); A.B., Reed College, 1956; Ph.D., Rutgers, 1961.

Fred Richard Schwirzke, Associate Professor of Physics (1967); B.S., Univ. of Rostock, 1950; M.S., Univ. of Karlsruhe, 1953; Ph.D., 1959.

Theodore Joseph Williamson, Associate Professor of Physics (1967); B.S., Univ. of Washington, 1964; M.S., 1965; Ph.D., 1967.

Oscar Bryan Wilson, Jr., Professor of Physics (1957); B.S., Univ. of Texas, 1944; M.A., Univ. of California at Los Angeles, 1948; Ph.D., 1951.

Karlheinz Edgar Woehler, Professor of Physics (1962); B.S., Univ. of Bonn, 1953; M.S., Technical Univ., Aachen, 1955; Ph.D., Univ. of Munich, 1962.

William Bardwell Zeleny, Associate Professor of Physics (1962); B.S., Univ. of Maryland, 1956; M.S., Syracuse Univ., 1958; Ph.D., 1960.

EMERITUS FACULTY

Austin Rogers Frey, Distinguished Professor Emeritus (1946); B.S., Harvard Univ., 1920; M.S., 1924; Ph.D., 1929.

Lawrence Edward Kinsler, Distinguished Professor Emeritus (1946); B.S., California Institute of Technology, 1931; Ph.D., 1934.

* *The year of joining the Postgraduate School Faculty is indicated in parentheses.*

DEPARTMENT REQUIREMENTS FOR DEGREES IN PHYSICS

BACHELOR OF SCIENCE IN PHYSICS

1. A major in physics must include a minimum of 45 quarter hours in physics, including required courses and electives, a minimum of 24 quarter hours in mathematics, and the equivalent of a course in general chemistry. A minimum of 17 quarter hours of elective credits must be chosen from the natural sciences or engineering, other than physics or mathematics. Seventy-two quarter hours must be clearly of upper division level.

2. The following specific requirements must be met: (courses marked with an asterisk must include a laboratory).

Subject	*Approximate Quarter Hrs.*
General Physics*	13
Analytical Mechanics	7
Electricity and Magnetism	6
Thermodynamics	3
Modern Physics* (containing material on atomic, nuclear and solid state physics)	10
	39

The mathematics courses shall include differential equations and vector analysis.

3. Minor departures from these requirements may be approved by the Department as long as the total number of hours in upper division courses is not reduced.

4. The student must maintain grade point averages of at least 2.2 in both physics and mathematics.

MASTER OF SCIENCE IN PHYSICS

In recognition of the special needs of the Navy involving both the basic and applied branches of physics, the Master of Science degree is offered under two options.

BASIC PHYSICS OPTION

1. This option offers the student a broad education concentrating on the fundamental concepts of physics. It combines a solid scientific foundation with professional flexibility.

2. Each student's program of study must have a minimum of 30 quarter hours of physics courses (not including thesis) distributed between courses in the 3000 and 4000 series; of this 30 hours at least 15 hours must be from the 4000 series. Upon approval of the chairman of the physics department a maximum of 4 hours of courses taken in another department may be applied toward satisfying the above requirements. In lieu of the preceding requirement, students who are qualified to pursue graduate courses in physics when they arrive at the Postgraduate School may complete a minimum of 20 hours entirely of 4000 level physics courses. In addition, all students must engage in research in at least 3 quarters and present an acceptable thesis.

3. In addition to the courses normally leading to a Bachelor of Science in Physics, the following specific course requirements must be successfully completed for a student to earn the degree of Master of Science in Physics:

a. Thermodynamics and Statistical Mechanics — The student must take a two-quarter sequence or present equivalent preparation in this area.

b. A course in Advanced Mechanics or Quantum Mechanics.

c. A course in Electromagnetism at the 4000 level.

d. An advanced course in Modern Physics.

e. Specialization, to include at least two advanced courses, in one of the following areas:

(1) Acoustics
(2) Atomic Physics
(3) Nuclear Physics
(4) Plasma Physics
(5) Solid State Physics
(6) Underwater Physics
(7) Other, subject to Department approval

APPLIED PHYSICS OPTION

1. This option offers the engineering student an opportunity to achieve competence in areas of physics which are relevant to technical applications. It offers the physics student an opportunity to branch out into interdisciplinary areas of applied science and engineering.

2. The student's preparation for this program must include an upper division course in Thermal/Statistical Physics and a two-course sequence beyond the 1000 level in each of the following areas: Analytical Mechanics, Electricity and Magnetism, and Modern Physics. Any deficiences in the student's preparation may be removed by passing the appropriate physics courses. However, such courses shall not count toward the minimum requirements listed below.

3. Each student's program of study must include a minimum of 20 quarter hours of physics courses (not including thesis) distributed between courses in the 3000 and 4000 series. He must also have a minimum of 8 quarter hours in a departmentally approved sequence of courses in the 3000 and 4000 series; this sequence should emphasize a specific application of physics and should be outside the Physics Department. Of these required 28 quarter hours, at least 12 must be at the 4000 level and at least 6 of these 12 must be in physics. In addition, all students must engage in research in at least 3 quarters and present an acceptable thesis. This research will usually be performed in the Physics Department, but it may be performed in another department with prior approval of both departments.

DOCTOR OF PHILOSOPHY

The Ph. D. degree is offered in the Physics Department in several areas of specialization which currently include Acoustics, Atomic Physics, Nuclear Physics, Plasma Physics, Solid State Physics and Theoretical Physics.

Requirements for the degree may be grouped into 3 catagories: courses, thesis research, and examinations in major and minor fields and languages.

The required examinations are described elsewhere in this catalogue in the section Requirements for the Doctor's Degree. In addition to the school requirements the department requires a preliminary examination to show evidence of acceptability as a doctoral student.

The usual courses to be taken by the candidate include Advanced Mechanics, Classical Electrodynamics, Quantum Mechanics and Statistical Physics. (PH 4171, 4371, 4971, 4972, 4973, 4571, 4572.) Suitable electives are to be chosen in physics and the minor fields, mainly from the list of graduate level courses.

Any prospective candidate should consult with the Graduate Student Advisor in the Physics Department for guidance in setting up the course of study.

PHYSICS LABORATORIES

The physics laboratories are equipped to carry on instructional and research work in nuclear physics, low temperatures and solid state physics, electro-optics, plasma physics, atomic physics and spectroscopy, and acoustics.

In low temperature and solid state physics the equipment includes nitrogen liquifiers, a Collins helium liquefier, He^3 refrigeration equipment to reach temperatures below 1°K, a 12 inch uniform field electromagnet, microwave gear for spin resonance and maser studies, and high frequency pulse acoustic equipment for phonon studies.

The plasma physics equipment includes a large plasma system, diagnostic equipment for studies of plasma dynamics, a steady state plasma source with magnetic fields up to 10,000 gauss and a giant pulse laser. The spectroscopy equipment includes a large grating spectrograph, a large prism spectrograph, and infrared spectrophotometer.

The acoustics laboratory equipment includes a large anechoic chamber, a small reverberation chamber, and a multiple-unit acoustics laboratory for student experimentation in airborne acoustics. Sonar equipment, test tanks, and instrumentation for investigation in underwater sound comprise the underwater acoustics laboratory.

The specroscopic data center contains a compre- *PH 1015, PH 1016, and PH 2017 comprise a series of courses*
hensive compilation of the known energy levels and atomic spectrum lines in the vacuum ultraviolet range.

The electro-optics laboratory equipment includes imaging and detecting systems from the far infrared to the visible range.

A two million volt Van de Graff generator is used both in nuclear and solid state research.

A 100 MeV electron linear accelerator with 5 microamp beam current is used in nuclear physics research as well as radiation effects in microcircuits.

PHYSICS

PH 0110 REFRESHER PHYSICS (5-3). A six-week course designed to refresh incoming students in selected basic concepts of mechanics and either thermodynamics or electricity and magnetism. The level of presentation and choice of material depend upon the background and needs of the students. The laboratory sessions are devoted to guided problem-solving. TEXT: A standard elementary physics text of appropriate level.

PH 0499 ACOUSTICS COLLOQUIUM (0-1). Reports on current research and study of recent research literature in conjunction with the student thesis. PREREQUISITE: A course in acoustics.

PH 0810 THESIS RESEARCH (0-0). Every student conducting thesis research will enroll in this course.

PH 0999 PHYSICS COLLOQUIUM (0-1). Discussion of topics of current interest in the field of physics and student thesis reports.

Lower Division Courses

PH 1005, PH 1006, and PH 1007 comprise a series of courses intended for students with limited backgrounds in mathematics.

PH 1005 ELEMENTARY PHYSICS I (4-2). Mechanics, Heat, and Sound. Lectures, problem sessions, and laboratory. Physical quantities and the concepts of motion, force, momentum, and energy. The mechanics of gases, heat transfer, and thermodynamics. Simple harmonic motion and propagation of sound. TEXT: Sears and Zemansky, *College Physics*, or equivalent.

PH 1006 ELEMENTARY PHYSICS II (3-2). Electricity and Magnetism. Electrostatics, electric current, and magnetism. Lectures, problem sessions, and laboratory. TEXT: Sears and Zemansky, *College Physics*, or equivalent. PREREQUISITE: PH 1005.

PH 1007 ELEMENTARY PHYSICS III (4-2). Optics and Modern Physics. Lectures, problem sessions and laboratory dealing with geometrical optics, mirrors and lenses. Atomic structure, optical spectra, radioactivity and nuclear structure. TEXT: Sears and Zemansky, *College Physics*, or equivalent. PREREQUISITES: PH 1005 and PH 1006.

PH 1011, PH *1012, and PH 2017 comprise a series of courses intended primarily for Engineering Science students with a prior knowledge of calculus.*

PH 1011 BASIC PHYSICS I (4-0). Mechanics, Heat, and Sound. Review of Newtonian Mechanics. Conservation laws. Rotational motion. Thermal properties of gases, liquids and solids. Laws of Thermodynamics. Wave motion and propagation of sound. TEXT: Resnick-Halliday, *Physics, Part I.* PREREQUISITES: Courses in college physics and college mathematics through calculus.

PH 1012 BASIC PHYSICS II (4-0). Electricity and Magnetism. Electrostatics stressing Gauss' Law and the theory of electric fields and potentials. Alternating current. Electromagnetism. TEXT: Halliday-Resnick, *Physics, Part II.* PREREQUISITE: PH 1011.

PH 1015, PH 1016, and PH 1017 comprise a series of courses intended primarily for BS students and provide a knowledge of the principles of physics and a scientific background for the study of engineering.

PH 1015 BASIC PHYSICS I (5-3). Mechanics, Heat, and Sound. Lectures, problem sessions, and laboratory. Concepts of force, motion, energy, and momentum; thermal properties of gases, liquids, and solids, and wave motion. TEXT: Halliday-Resnick, *Physics, Part I.* PREREQUISITE: One quarter of calculus.

PH 1016 BASIC PHYSICS II (4-3). Electricity and Magnetism. Lectures, problem sessions, and laboratory. Electrostatics, electromagnetism, electrochemistry, and direct and alternating currents. TEXT: Halliday-Resnick, *Physics, Part II.* PREREQUISITE PH 1015.

PH 1041 REVIEW OF MECHANICS AND ELECTRICITY AND MAGNETISM (5-1). First quarter of a sequence of fun-

damental physics for students in Electrical Engineering and Electronics. *(The sequence includes PH 1041, 2241, 2641* and *3741.)* The subject matter of this course includes: kinematics, dynamics, conservation laws, electrostatics, Coulomb's and Gauss' laws, electric and magnetic fields, Ampere's and Faraday's laws, capacitance and inductance. TEXT: Halliday and Resnick, *Physics, Vol. II;* Instructor's Notes.

PH 1051 REVIEW OF VECTOR MECHANICS AND OPTICS (4-2). A review of the basic concepts of elementary vector mechanics and geometrical optics, including: statics, motion in one dimension and in a plane, particle dynamics, energy, momentum, rotational dynamics, and the laws of reflection and refraction applied to lenses, mirrors, and prisms. The laboratory sessions are devoted to guided problem-solving. TEXT: Resnick-Halliday, *Physics, Parts I and II.* PREREQUISITES: Previous courses in general physics and calculus.

PH 1901 THE NATURE AND STRUCTURE OF PHYSICS I (4-2). The development of ideas and measurement leading from early models of the heavens through Galileo and Kepler to Newton and the Theory of Universal Gravitation. Satellites, natural and artificial. The concepts central to classical mechanics: momentum, kinetic and potential energies; conservation principles. Questions about the nature of light. Wave motion and wave properties of light. TEXT: Leon Cooper, *Introduction to the Meaning and Structure of Physics, Short ed.;* selected collateral readings.

PH 1902 THE NATURE AND STRUCTURE OF PHYSICS II (4-2). Fundamental concepts of electromagnetism and light as electromagnetic radiation. Experiments with light and the crisis of classical physics. Einstein and Relativity; space and time revised, mass-energy equivalence. The question of atomic structure and the quantum interpretation. Properties of atoms, nuclei, and particles. TEXT: Same as PH 1901. PREREQUISITE: PH 1901.

PH 1903 PHYSICS AND MODERN DEVICES (3-2). Development of the physical foundations of some recent technological devices of interest to the Naval Officer. The topics will be selected according to the interests of the class and instructor and could include items such as lasers, magnetometers, underwater detection, nuclear fission and fusion, solid state electronics. TEXT: Selected readings from the reference library. PREREQUISITE: PH 1902 or consent of the Instructor.

Upper Division Courses

PH 2017 BASIC PHYSICS III (4-2). Optics and Modern Physics *(PH 2017 is the third course for both the PH 1011, PH 1012, and the PH 1015, PH 1016 series of Basic Physics).* Lectures, problem sessions, and laboratory. Geometrical optics, mirrors and lenses. Interference and diffraction. Special relativity, quantum effects of waves and particles, structure of the hydrogen atom, nuclear structure, and nuclear reactions. TEXTS: Halliday-Resnick, *Physics, Part II,* and Weidner and Sells, *Elementary Modern Physics.* PREREQUISITES: PH 1011 and PH 1012 or PH 1015 and PH 1016.

PH 2121 ANALYSIS OF PHYSICAL MODELS I (4-0). The first in a sequence of two courses (PH 2121, PH 2122) designed for students in the Operations Analysis curriculum. The process of constructing an analytical model is developed using the classical ballistic motion of an object in a gravitational field as an example. The need for a model of increasing sophistication to represent a real physical system is illustrated and the limits of validity of over-simplified models are stressed. Specific topics include projectile motion in a uniform gravitational field, effects of air resistance, rocket motion, ballistic trajectories in an inverse-square field, effects of the earth's rotation and shape, and the breakdown of the Newtonian model in the limits of small systems or large velocities. TEXT: Instructor's Notes.

PH 2122 ANALYSIS OF PHYSICAL MODELS II (4-2). The second in a sequence of courses (PH 2121, PH 2122) designed for students in the Operations Analysis curriculum. The concept of wave motion as an analytical model is developed using optical phenomena as the principle example. The similarities in the predictions of wave theory as applied to optical, microwave, and acoustical systems are stressed and the limits of validity of the model are presented. Specific topics include simple harmonic motion, basic properties of waves, reflection and refraction, interference and diffraction, frequency analysis, geometric optics as a limit of wave optics, resolution limitations, photon theory of light and wave-particle duality, and applications of wave theory to military optical systems, antenna and sonar arrays, and propagation of microwave and communication signals. TEXT: Instructor's Notes. PREREQUISITE: PH 2121.

PH 2151 MECHANICS I (4-0). Kinematics and dynamics in two and three dimensions. The damped harmonic oscillator. The gravitational two-body problem. TEXT: Symon, *Mechanics, 3rd ed.* PREREQUISITES: PH 1051, calculus, vector algebra, and ordinary differential equations (the latter may be taken concurrently).

PH 2152 MECHANICS II (4-0). Motion of a system of particles, conservation laws, rigid body motion, rotating coordinate systems, Lagrangian mechanics. Additional topics as time allows: mechanics of continuous media, gravitational potential theory. TEXT: Symon, *Mechanics, 3rd ed.* PREREQUISITE: PH 2151.

PH 2241 WAVES AND PARTICLES (4-0). Second quarter of a sequence of fundamental physics for students in Electrical Engineering and Electronics. Wave propagation, interference, diffraction, polarization. Electromagnetic waves. Photoelectric and Compton effects. Wave particle dualism. Black body radiation, spectra, Bohr atom. TEXTS: Instructor's Notes; Young, *Optics and Modern Physics;* Weidner and Sells, *Elementary Modern Physics.* PREREQUISITES: PH 1041 or PH 1051.

PH 2251 WAVES AND PARTICLES (4-2). A course designed to provide the background and fundamental ideas in modern physics which are utilized in atomic, molecular, solid state, and nuclear physics. Wave properties; propagation, interference, diffraction, polarization. Electromagnetic waves. The special theory of relativity. Photoelectric and Compton effects. Wave-particle dualism; de Broglie hypothesis and introduction to the Schroedinger equation; electron diffraction; wave packets. Continuous and line spectra; black-body radiation; hydrogen atom spectrum. TEXTS: Eisberg, *Fundamentals of Modern Physics;* Instructor's Notes. PREREQUISITES: PH 1051, MA 2121.

PH 2351 ELECTROMAGNETISM I (4-0). Properties of electric and magnetic fields and the development of Maxwell's Equations: electrostatic fields and potential in free space and dielectrics, the magnetic fields and potentials of steady currents in free space and permeable materials, electromagnetic induction, Maxwell's Equations, and Poynting's Theorem. TEXT: Durney and Johnson, *Introduction to Modern Electromagnetics.* PREREQUISITES: PH 1051 and MA 2161 or equivalent.

PH 2352 ELECTROMAGNETISM II (4-0). Properties of electromagnetic waves: wave equations; propagation of plane waves in free space, dielectrics, conductors, and plasmas; reflection and refraction of plane waves; two-conductor transmission lines; and rectangular wave guides. TEXT: Durney and Johnson, *Introduction to Modern Electromagnetics.* PREREQUISITE: PH 2351.

PH 2551 THERMODYNAMICS (3-0) (may be taught as CH 2401). Fundamental theory of thermodynamics and applications

to physical systems. First and second laws of thermodynamics; entropy; thermodynamic potentials; applications to gases, liquids, radiation, and magnetic materials; equilibrium. TEXT: Vanderslice, Schamp, and Mason, *Thermodynamics*. PREREQUISITE: PH 1051 and calculus of several variables.

PH 2641 ATOMIC PHYSICS (4-2). Third quarter in the sequence of fundamental physics for students in Electrical Engineering and Electronics. Bohr model. Schroedinger equation, exact solution for hydrogen atom, electron spin, periodic table, atomic spectra, transition probabilities, Einstein coefficients and stimulated emission, molecules and molecular spectra. TEXT: Richtmeyer, Kennard and Cooper, *Modern Physics*. PREREQUISITE: PH 2241 or PH 2251.

PH 2645 MODERN PHYSICS (4-2). Interference, phase and group velocity, wave particle duality, Bohr atom, spectra, 1-dimensional wave mechanics, Schroedinger equation and applications including hydrogen atom, periodic table, spin-orbit interaction, quantum electronic devices. TEXT: Beiser, *Perspectives of Modern Physics*. PREREQUISITES: PH 2241 or equivalent, MA 2121.

PH 2810 SURVEY OF NUCLEAR PHYSICS (4-0). A course designed to introduce the student to the ideas of nuclear physics, with emphasis on neutron physics and reactors. Atomic nature of matter; wave-particle duality; the nuclear atom. Basic nuclear properties; reactions, neutrons and fission. Reactors. TEXTS: Weidner and Sells, *Elementary Modern Physics*; Murray, *Introduction to Nuclear Engineering*.

Upper Division or Graduate Courses

PH 3154 PHYSICS OF SPACE VEHICLE DYNAMICS (3-0). Basic physical principles are applied to study the trajectories of satellites and missiles: orbits in the inverse-square force field are developed, including the role of initial (launch) conditions, followed by rendezvous problems, transfer between orbits, synchronous satellites, perturbations due to oblateness of the earth. An introduction to launch and re-entry problems is given, including multistage rockets. Advanced propulsion methods. TEXT: Thomson, *Introduction to Space Mechanics*. PREREQUISITES: PH 2152 or equivalent mechanics course.

PH 3157 PHYSICS OF CONTINUA (4-0). The continuum hypothesis. Cartesian tensors. The concept of stress. Deformation. Conservation of mass, momentum and energy. Theory of constitutive equations. Applications to fluid mechanics, solid mechanics and wave phenomena. TEXT: Scipio, *Principles of Continua With Applications*. PREREQUISITE: PH 2151.

PH 3161 PHYSICS OF UNDERWATER VEHICLES (4-1). Physical properties of liquids. Solutions to potential flow problems. Viscous flows; the laminar boundary, turbulence, and separation. Cavitation. Special topics may include: hydrodynamic noise, resistance of surface ships, and drag reduction techniques. TEXT: Michelson, *The Science of Fluids*. PREREQUISITES: Vector calculus (e.g., MA 2161), and mechanics (e.g., PH 1051).

PH 3280 ELECTRO-OPTICS (4-2). Refracting systems; atmospheric and underwater transmission, scattering, and scintillation; diffraction and Fourier transform methods; coherent optics, Fourier plane filters, holography; fiber and film optics; electro-optic detectors; infrared techniques; image intensifiers; lasers and applications; nonlinear optics. TEXT: G. R. Fowles, *Introduction to Modern Optics*. PREREQUISITE: A course in atomic physics.

PH 3421 UNDERWATER ACOUSTICS (4-2). A course taught primarily for students in Operations Analysis curricula. An analytical survey of acoustics with an emphasis on sound propagation in the ocean. Topics include: Damped and forced harmonic oscillations; Wave equation in an ideal fluid; Simple harmonic solutions for plane and spherical waves; Radiation of sound; Propagation effects due to boundaries, inhomogeneities and sound absorbing processes. Development of the basic models for sonar; Transducers for underwater sound. Laboratory experiments on underwater acoustics, spectrum analysis and transducers. TEXTS: Kinsler and Frey, *Fundamentals of Acoustics*; Urick, *Principles of Underwater Sound for Engineers*. PREREQUISITES: Differential equations and a course in mechanics and fundamentals of wave motion.

PH 3422 MILITARY APPLICATIONS OF UNDERWATER ACOUSTICS (3-1). A detailed study of the application of acoustics to the detection, classification, and localization of underwater targets. Topics covered include propagation modes, ray theory and normal mode transmission models, techniques for detecting an echo in competition with noise and reverberation, probabilistic aspects of the sonar equation, and some human factors in ASW. Practical examples are taken from problems of surveillance, air and surface sonar systems (both passive and active), and other areas of interest to the students. TEXTS: Urick, *Principles of Underwater Sound for Engineers*; and Instructor's Notes. PREREQUISITE: A course in underwater acoustics or consent of Instructor.

PH 3431 PHYSICS OF SOUND IN THE OCEAN (3-1). A survey of physical acoustics with an emphasis on propagation in the ocean, taught primarily for students in oceanography curricula. Topics treated include: simple harmonic motion; the acoustic wave equation in fluids and its solutions for both plane and diverging waves; ray acoustics; radiation of sound; reflection from boundaries; normal mode propagation; effects due to inhomogeneities and to sound absorption; an introduction to models for sonar systems; transducers for underwater sound. Laboratory experiments on underwater acoustics, spectrum analysis and transducers. TEXTS: Kinsler and Frey, *Fundamentals of Acoustics*; Urick, *Principles of Underwater Sound for Engineers*. PREREQUISITES: A course in general physics and a course in differential equations.

PH 3451 FUNDAMENTAL ACOUSTICS (4-1). Mechanics of free, forced, and damped simple vibratory systems. Mechanical impedance. Development of, and solutions to the acoustic wave equations in extended media. Propagation of plane waves in fluids and between media. Specific acoustical behavior of the piston source. Radiation impedance. Lumped acoustic elements and propagation in pipes. Steady state response of acoustic waveguides. Group and phase velocities. Normal Modes. Laboratory experiments on selected topics. TEXTS: Kinsler and Frey, *Fundamentals of Acoustics*; Instructor's Notes. PREREQUISITES: A course in mechanics (e.g., PH 1051); Differential Equations (e.g. MA 2121).

PH 3452 UNDERWATER ACOUSTICS (4-2). Loudspeakers and microphones. Sound absorption and dispersion for classical and relaxing fluids. Transmission of sound in the ocean: the eikonal equation and necessary conditions for ray acoustics, method of images, refraction and ray diagrams, mode propagation in shallow water and refraction channels. Ambient noise and reverberation. Target strength. The sonar equations for active and passive systems. Laboratory experiments on selected concepts. TEXTS: Kinsler and Frey, *Fundamentals of Acoustics*; Urick, *Principles of Underwater Sound for Engineers*. PREREQUISITE: PH 3451.

PH 3461 EXPLOSIVE SHOCK WAVES (4-0). Generation and propagation of explosive shock waves in air and water including Rankine-Hugoniot equations, scaling laws, reflection and refraction phenomena, and experimental data. Shock loads on ships and blast loads on structures. Damage mechanism and

principles of protection against damage. TEXTS: Instructor's Notes; Cole, *Underwater Explosions;* Kinney, *Shocks in Air.* PREREQUISITES: PH 2551 or CH 2401, and PH 2151 or PH 3451.

PH 3463 SPECIAL TOPICS IN UNDERWATER ACOUSTICS (3-2). A terminal course following PH 3452 for those students who do not pursue a graduate level program. Topics may include additional material in underwater acoustics, transducer theory, non-linear phenomena in acoustics, explosive waves in water, noise and vibration control. Laboratory experiments on related material. TEXT: Instructor's Notes. PREREQUISITE: PH 3452 or equivalent.

PH 3561 INTRODUCTORY STATISTICAL PHYSICS (4-0). Distribution functions, kinetic theory, transport processes, introduction to classical and quantum distributions. Applications to gases, solids, and radiation. TEXT: Kittel, *Thermal Physics.* PREREQUISITES: PH 2152, PH 2551 or CH 2401, PH 3651.

PH 3651 ATOMIC PHYSICS (4-2). Properties of the electron, the nuclear atom, the Bohr theory of the hydrogen atom, atomic energy levels, the Schroedinger Equation and properties of its solutions, application of the Schroedinger Equation to the square potential well and to the hydrogen atom, angular momentum operator, electron spin, identical particles, the Pauli Principle, multielectron atoms, the Periodic Table, the vector model of the atom and complex spectra, the Zeeman effect, Einstein coefficients and stimulated emission of radiation. TEXTS: Eisberg, *Fundamentals of Modern Physics;* Richtmeyer, Kennard & Cooper, *Introduction to Modern Physics.* PREREQUISITES: PH 2251 and MA 2161 or equivalent.

PH 3652 ELEMENTS OF MOLECULAR, SOLID STATE, AND NUCLEAR PHYSICS (4-2). X-ray spectra and Bragg's law, molecular bonds, excited states of molecules, molecular spectra. Bonding in crystals. Conduction in solids, band theory. Semiconductors. Fundamentals of nuclear physics, radioactivity and the decay law. Interaction of charged particles and photons with matter. TEXTS: Richtmeyer, Kennard and Cooper, *Introduction to Modern Physics;* Enge, *Introduction to Nuclear Physics;* Instructor's Notes. PREREQUISITE: PH 3651.

PH 3687 PHYSICS OF ELECTRON INTERACTION IN GASES (3-0). This course stresses the basic electronic processes in gases, fundamental to the physics and chemistry of the upper atmosphere and to the operation of electron devices including the gas laser. Topics covered include elastic collisions, free and ambipolar diffusion, mobility, excitation and ionization, charge transfer, emission from surfaces, recombination, high frequency and d.c. breakdown, sheaths, the glow and arc discharges, radiation, application to the gas laser. TEXT: Brown, *Introduction to Electrical Discharges in Gases;* McDaniel, *Collision Phenomena in Gases.* PREREQUISITES: PH 2641 or PH 3651 or consent of the Instructor.

PH 3741 ELECTRONIC PROPERTIES OF METALS AND SEMI-CONDUCTORS (4-2). Fourth quarter in the sequence of fundamental physics for students in Electrical Engineering and Electronics. Crystals and lattice properties, X-ray diffraction, free-electron theory, electrical conductivity, band theory. Brillouin zones, effective mass, holes, intrinsic and impurity semiconductors, diodes, transistors, thermoelectric effects, minority carriers, modern devices. TEXTS: Kittel, *Introduction to Solid State Physics, 3rd ed.;* and McKelvey, *Solid State and Semiconductor Devices.* PREREQUISITES: PH 2641 or PH 3651 or PH 2645.

PH 3745 DIELECTRIC AND MAGNETIC PROPERTIES (4-0). Electric and magnetic polarizabilities, internal fields, dielectric relaxation, ferroelectricity, resonance and masers, ferro- and anti-ferromagnetism, domains, bubble domains, Faraday rotation and microwave devices, optical properties, electromagnetic radiation detectors. PREREQUISITES: PH 2641 or PH 2645 or PH 3651.

PH 3921 CONCEPTUAL MODELS OF MODERN PHYSICS (4-0). A review of the conceptual development of modern physics selected to illustrate the principles of model building and the methodology of science and to serve as a foundation for understanding aspects of current technology. Topics illustrate the need for the introduction of two distinct probabilistic models in physics: statistical mechanics and quantum mechanics. The development of ideas in atomic physics, quantum mechanics and nuclear physics is traced. The treatment is largely historical and stresses the interplay between experimental results and theoretical models. TEXT: Instructor's Notes. PREREQUISITE: PH 2122.

PH 3951 INTRODUCTION TO QUANTUM MECHANICS (4-0). The general principles of quantum mechanics. Schroedinger equation. Harmonic oscillator. Angular momentum, many particle systems, electron spin, the Pauli exclusion principle. Time independent and time dependent perturbation, and the semi-classical theory of radiation applied to atomic transitions. TEXT: Park, *Introduction to Quantum Theory.* PREREQUISITES: PH 2351, MA 2161 or equivalent, PH 3651 (may be taken concurrently).

PH 3998 STUDIES IN INTERMEDIATE PHYSICS (2-0 to 4-0). Supervised study in one of the fields of intermediate physics selected to meet the needs of the student. TEXT: Instructor's Choice. PREREQUISITE: Consent of the Department Chairman.

Graduate Courses

PH 4151 PHYSICS OF ATMOSPHERIC REENTRY I (4-0). This is the first of a two-course sequence designed around the reentry problem in order to introduce a broad variety of physical theories and problems relevant in modern technology. The foundation is an introduction to continuum physics and phenomenological transport theory; kinetic transport theory; Boltzmann equation; transport coefficients; fluid dynamics; and viscous compressible flow with heat addition. The physics of shock waves is covered. A coverage of thermodynamic properties of high temperature gases leads to the next course and connects to plasma physics. TEXT: Instructor's Notes. PREREQUISITES: PH 2152, PH 2352, PH 3561, or equivalent.

PH 4152 PHYSICS OF ATMOSPHERIC REENTRY II (4-0). The second course of a sequence. More complex gas dynamics processes in which radiative phenomena are important are introduced. Radiative transport and radiative equilibrium. The combined laws of gas dynamics and radiation theory are applied to the reentry problem. Communication/detection problems associated with plasma sheaths are covered. The course concludes with topics from the physics of nuclear detonations, their effects on materials, and the electromagnetic pulse and blackout associated with nuclear detonations. TEXTS: Instructor's Notes; Pai, *Radiation Gas Dynamics.* PREREQUISITE: PH 4151.

PH 4162 FLUID MECHANICS (3-0). An advanced study of the physical bases of fluid mechanics: Fundamental concepts of continuum mechanics. Fluid mechanical models. Theory of hydrodynamic stability. Lighthill's theory of aerodynamically produced sound. Effects of compressibility. Fluid dynamic discontinuities, shock waves, and the method of characteristics. TEXT: Instructor's Notes. PREREQUISITE: A course in hydrodynamics (e.g., PH 3161).

PH 4171 ADVANCED MECHANICS (4-0). Hamilton's Principle. The equations of motion in Lagrangian and Hamiltonian form. The inertia tensor and rigid bodies. Canonical transforma-

tions and Poisson brackets. Small oscillations. Additional topics as time allows: Hamilton-Jacobi theory, perturbation theory. TEXT: Goldstein, *Classical Mechanics*. PREREQUISITES: PH 2152, PH 2352.

PH 4281 ELECTRO-OPTIC DEVICES (4-0). Infrared, visible and ultraviolet detectors and their limitations; electron optical devices; scanning devices; image displays and storage techniques; starlight viewing devices; viewing devices for self-luminous infrared sources; optical tracking; lasers and applications; coherent optical information processing and holography; nonlinear optical devices; optical heterodyning; acoustic-optic devices; fiber and film optical devices; optical signal processing and switching. TEXT: R. Hudson, *Infrared System Engineering*. PREREQUISITE: PH 3280 and a corequisite course in solid state physics.

PH 4353 ELECTROMAGNETISM III (3-0). Classical radiation theory: retarded potentials, Lienard-Wiechert potentials, fields of a fast electron, angular distribution and frequency spectrum of radiation from an accelerated point charge, Cherenkov radiation, Hertz potentials and dipole radiation, and radiation from linear antennas. TEXTS: Marion, *Classical Electromagnetic Radiation;* and Instructor's Notes. PREREQUISITE: PH 2352.

PH 4371 CLASSICAL ELECTRODYNAMICS (3-0). Tensors in special relativity. Classical relativistic electromagnetic field theory. Lorentz electron theory. TEXTS: Landau and Lifshitz, *Classical Theory of Fields*. PREREQUISITES: PH 4353 and familiarity with the special theory of relativity and Lagrangian Mechanics.

PH 4453 PROPAGATION OF WAVES IN FLUIDS (4-0). An advanced treatment of special topics related to sound propagation in the ocean, including: multipole radiation fields, incoherence and coherence; applications of the Helmholtz Integral; probability density functions, correlations and frequency spectra of sound scattered from rough boundaries; macrosonics, including non-linear propagation and shock wave phenomena. TEXTS: Instructor's Notes; and selected references in books such as: Beckmann and Spizzichino, *The Scattering of Electromagnetic Waves from Rough Surfaces;* Lindsay, *Mechanical Radiation;* Morse and Ingard, *Theoretical Acoustics;* Tolstoy and Clay, *Ocean Acoustics;* Cole, *Underwater Explosions*. PREREQUISITES: PH 3452 or consent of instructor.

PH 4454 TRANSDUCER THEORY AND DESIGN (3-2). A treatment of the fundamental phenomena basic to the design of transducers for underwater sound and specific examples of their application. Topics include piezoelectric, magnetostrictive and hydromechanical effects. Laboratory experiments on measurement techniques, properties of transducer materials and characteristics of typical transducer types. TEXT: Instructor's Notes; and selected references. PREREQUISITE: PH 3452 or equivalent.

PH 4455 ADVANCED ACOUSTICS LABORATORY (0-3). Advanced laboratory projects in acoustics. PREREQUISITE: PH 3452 or equivalent.

PH 4456 SEMINAR IN APPLICATIONS OF UNDERWATER SOUND (3-0). A study of current literature on applications of acoustics to problems of naval interest. PREREQUISITE: PH 4453 or consent of instructor.

PH 4571 STATISTICAL PHYSICS I (3-0). Kinetic theory and the Boltzmann theorem, configuration and phase space, and the Liouville theorem, ensemble theory, microcanonical, canonical, and grand canonical ensembles, quantum statistics. TEXT: Huang, *Statistical Mechanics*. PREREQUISITES: PH 2152, PH 3651, PH 2551.

PH 4572 STATISTICAL PHYSICS II (3-0). A continuation of PH 4571 with applications to molecules, Bose-Einstein gases, Fermi-Dirac liquids, and irreversible processes. TEXT: Huang, *Statistical Mechanics*. PREREQUISITE: PH 4571.

PH 4630 SPACE PHYSICS I — PHYSICS OF THE UPPER ATMOSPHERE (4-0). Structure of the upper atmosphere. Atmospheric absorption in the infrared, visible and ultraviolet. The ionosphere. Geomagnetic field and the radiation belts. Disturbances of the upper atmosphere. Magnetic field, the magnetopause and solar wind. Experimental instrumentation in space research. TEXTS: Hines et al, *Physics of the Earth's Upper Atmosphere;* Hess, *Introduction to Space Science*. PREREQUISITES: PH 2352 and PH 3652 or consent of the instructor.

PH 4631 SPACE PHYSICS II - PHYSICS OF THE SOLAR SYSTEM (4-0). Solar interior and surface. Solar magnetic field, sunspots and flares. Emissions from the sun. Introduction to stellar evolution and cosmology. TEXTS: Brandt, *Solar System Astrophysics;* Hess, *Introduction to Space Science*. PREREQUISITE: Consent of the Instructor.

PH 4661 PLASMA PHYSICS I (4-0). Introduction to the physical and mathematical concepts fundamental to various branches of plasma physics and space physics such as ionospheric communications, advanced propulsion, and controlled fusion. Topics covered include single particle motions in electromagnetic fields, orbit theory, collision phenomena, breakdown in gases, and diffusion. The Boltzmann equation and the macroscopic momentum and energy transport equations are discussed. The magnetohydrodynamic and the two-fluid plasma models are considered. TEXTS: Tanenbaum, *Plasma Physics;* Rose and Clark, *Plasmas and Controlled Fusion*. PREREQUISITES: PH 2352, PH 3561, PH 3651, or the equivalent.

PH 4662 PLASMA PHYSICS II (3-0). A continuation of Plasma Physics I. Applications of the hydromagnetic equations to the study of macroscopic motions of a plasma. Effect of Coulomb interactions, relaxation times and runaway electrons. Small amplitude plasma waves, shock waves. Radiation from plasmas, including bremsstrahlung and cyclotron radiation. Plasma instabilities. TEXTS: Tanenbaum, *Plasma Physics;* Rose and Clark, *Plasmas and Controlled Fusion*. PREREQUISITES: PH 4353, PH 4661 or equivalent.

PH 4681 ADVANCED PLASMA PHYSICS (3-0). Selected topics in plasma physics, such as waves in anisotropic plasmas, turbulence and fluctuations, collisionless shock waves. PREREQUISITES: PH 4662 or consent of the instructor.

PH 4685 ADVANCED ATOMIC PHYSICS (3-0). Selected topics in atomic spectroscopy and atomic collisions. Classical and quantum description of the collision process, transition probabilities and line broadening mechanisms. TEXTS: Shore and Menzel; *Principles of Atomic Spectra;* McDaniel, *Collision Phenomena in Ionized Gases*. PREREQUISITES: PH 3651 and consent of the instructor.

PH 4750 RADIATION EFFECTS IN SOLIDS (5-0). The effects of nuclear radiation and the effects of shock waves on the properties of solids: interaction of radiation with solids, displacement of atoms in solids and the effects on solid state properties; effects on electrons in the solids; effects of shock compression of solids, behavior beyond the elastic limit, phase changes. TEXT: Instructor's Notes. PREREQUISITES: PH 3461, PH 3561, PH 3652.

PH 4760 SOLID STATE PHYSICS (4-2). Fundamental theory and related laboratory experiments dealing with solids: crystals, binding energy, lattice vibration, dislocations and mechanical properties, free electron theory, band theory, properties of semiconductors and insulators, magnetism. TEXT: Kittel, *Introduction to Solid State Physics, 3rd ed.* PREREQUISITE: PH 3651 and PH 3561 (the latter may be taken concurrently.)

PH 4781 APPLICATIONS OF SOLID STATE PHYSICS I (3-0). Detailed studies of selected topics in modern applications of solid state physics. Typical courses might include: radiation effects in electronic devices, infrared detectors, dielectric and

magnetic properties. PREREQUISITES: PH 3561, PH 3741 or PH 4760.

PH 4782 APPLICATIONS OF SOLID STATE PHYSICS II (3-0). Detailed studies of selected topics in modern applications of solid state physics. PH 4781 and PH 4782 can be taken in alternate years or in different quarters of the same year. PREREQUISITES: PH 3561, PH 3741 or PH 4760.

PH 4790 THEORY OF QUANTUM DEVICES (3-0). Theory of the operation of electronic devices depending on energy states and the quantum nature of radiation; topics in quantum mechanics, spin resonance, rotating coordinates, relaxation times, internal fields: application to specific electronic devices, parametric amplifiers, magnetic instruments. TEXTS: Siegman, *An Introduction to Lasers and Masers;* Pake, *Paramagnetic Resonance;* Heavens, *Optical Masers;* Bloembergen, *Nonlinear Optics.* PREREQUISITES: PH 2641 or PH 3651.

PH 4851 NUCLEAR PHYSICS I (4-2). Nuclear decay schemes and energetics; nuclear forces; the deuteron and low energy nucleon-nucleon scattering; partial wave analysis of scattering; neutron-induced reactions and the Breit-Wigner formula; nuclear fission and fusion; nuclear reactors. TEXT: Choice of Instructor. PREREQUISITES: PH 3652, PH 3951 and PH 2352.

PH 4852 NUCLEAR PHYSICS II (3-0). A continuation of PH 4851. This course treats more advanced topics in nuclear physics. Nuclear moments; nuclear models; isotopic spin, the quantum mechanics of alpha, beta and gamma decay; parity nonconservation; topics selected by class interest. TEXT: Choice of Instructor. PREREQUISITE: PH 4851.

PH 4855 METHODS IN RADIATION DOSIMETRY (3-2). An intensive study of the principles and methods of radiation dosimetry with emphasis on those aspects of dosimetry pertinent to routine health physics practice. The course examines the various quantities and units of dosimetry, the mathematical modeling of radiation fields, interactions of radiation with matter, instrumentation for dosimetry and applications to various radiation environments. The legal and protection aspects of dosimetry are examined in detail. Laboratory work is primarily concerned with proper techniques for evaluating radiation fields. PREREQUISITES: EE 2201, EE 4802 or BI 3850, and PH 3652 (may be taken concurrently).

PH 4881 ADVANCED NUCLEAR PHYSICS I (3-0). Selected topics in nuclear and particle physics. The particular subjects covered will depend on the needs of the students and choice of the Instructor. PREREQUISITES: PH 4851 and PH 3951 or PH 4971.

PH 4882 ADVANCED NUCLEAR PHYSICS II (3-0). A continuation of PH 4881. PREREQUISITE: PH 4881.

PH 4885 REACTOR THEORY (3-0). The diffusion and slowing down of neutrons. Homogeneous thermal reactors; time behavior; reactor control. Multigroup theory. Heterogeneous systems. TEXTS: Glasstone and Edlund, *The Elements of Nuclear Reactor Theory;* Murray, *Nuclear Reactor Physics.* PREREQUISITE: PH 3652.

PH 4922 TECHNOLOGICAL APPLICATIONS OF MODERN PHYSICS (4-0). A discussion of the physical basis of and applications of selected technologies which have developed from modern physics and are of current or potential military interest. For each technology discussed, the underlying principles will be reviewed, the historical development will be traced, current technical limitations will be presented, and specific military applications will be studied. Typical topics might be selected from: lasers, infra-red detection, nuclear weapons and ABM systems, solid state electronics, magnetic detection, etc. TEXT: Instructor's Notes. PREREQUISITE: PH 3921.

PH 4971 QUANTUM MECHANICS I (3-0). General principles of nonrelativistic quantum mechanics. Stationary states of the square well, the harmonic oscillator, and the hydrogen atom. TEXTS: Dirac, *Quantum Mechanics;* Merzbacher, *Quantum Mechanics.* PREREQUISITES: PH 3651 and PH 4171.

PH 4972 QUANTUM MECHANICS II (3-0). Addition of angular momenta. Time-independent and time-dependent perturbation theory. Scattering theory. Identical particles and spin. TEXTS: Dirac, *Quantum Mechanics;* Merzbacher, *Quantum Mechanics.* PREREQUISITES: PH 4971.

PH 4973 QUANTUM MECHANICS III (3-0). General principles of relativistic quantum mechanics. Properties and solutions of relativistic wave equations. TEXTS: Bjorken and Drell, *Relativistic Quantum Mechanics;* Instructor's Notes. PREREQUISITES PH 4371 and PH 4972.

PH 4981 QUANTUM FIELD THEORY I (3-0). General principles of quantum field theory. Quantization of scalar, spinor, and electromagnetic fields. TEXT: Muirhead, *The Physics of Elementary Particles.* PREREQUISITE: PH 4973.

PH 4982 QUANTUM FIELD THEORY II (3-0). Interacting fields. The S-matrix and renormalization. Strong, electromagnetic, and weak interactions. Introduction to dispersion relations. TEXT: Muirhead, *The Physics of Elementary Particles.* PREREQUISITE: PH 4981.

PH 4991 RELATIVITY AND COSMOLOGY (3-0). Einstein's general theory of relativity. The three classical tests. The Schwarzschild singularity and black holes. Cosmological models and their relations with observations. Introduction to modern developments: gravitational waves, Dicke's theory, problems of quantum cosmology and superspace. TEXT: Adler, Bazin, and Schiffer, *Introduction to General Relativity.* PREREQUISITE: PH 4371.

PH 4993 PHYSICAL GROUP THEORY (3-0). Invariance of quantum mechanical systems to certain groups of transformations. Topics to be selected from finite rotation groups and crystal symmetries, the continuous rotation group in three dimensions, transformation groups associated with elementary particle symmetries. TEXT: Tinkham, *Group Theory and Quantum Mechanics.* PREREQUISITE: PH 4972.

PH 4998 READING IN ADVANCED PHYSICS (2-0 to 4-0). Supervised reading in one of the fields of advanced physics selected to meet the needs of the student. May be repeated for credit in a different field. PREREQUISITE: Consent of the Instructor.

PH 4999 ADVANCED SEMINAR (1-0 to 3-0). A seminar in recent developments in basic and applied physics, conducted by faculty members with student participation. PREREQUISITE: The student should have graduate standing and the consent of the Instructor.

Other Courses

BI 3850 BIOLOGICAL EFFECTS OF RADIATION (5-0). This course treats the effects of radiation on individual living cells and on the whole mammalian organism, including man. Sufficient biological background material is presented, as required for an understanding of the radiation effects. Aspects of radiological safety are also treated. PREREQUISITES: PH 3652 and PH 2551.

GV/PH 2280 NUCLEAR WEAPONS AND FOREIGN POLICY (4-0). An interdisciplinary course which covers both the technology and political influences of nuclear weapons systems. The course will emphasize the interaction of nuclear weapons systems with the foreign policies of the major powers and political blocs from 1945-present.

NAVY MANAGEMENT SYSTEMS CENTER

MASON BEHR FREEMAN, Rear Admiral, U. S. Navy, Director; B.S., U. S. Naval Academy, 1935; Naval Postgraduate School, 1943; National War College, 1957.

HERMAN PAUL ECKER, Professor; Executive Director (1957)*; B.A., Pomona College, 1948; M.A., Claremont Graduate School, 1949; Ph.D., 1967.

IVON WILLIAM ULREY, Professor; Assistant Director, Research and Program Development (1966); B.S. Ohio State Univ., 1931; M.B.A., New York Univ., 1937; Ph.D., Ohio State Univ., 1953.

JOHN EDWARD DAWSON, Associate Professor; Assistant Director, Academic Programs (1966); B.A., The Principia College, 1953; M.P.A., Syracuse Univ., 1954; D.P.A., 1971.

ARTHUR STEPHEN KELLER, Commander, U. S. Naval Reserve; Assistant Director, Administration and Logistics (1970); B.S., Madison College, 1952; M.B.A., Western Michigan Univ., 1967.

ROBERT MOFFAT ALLAN, JR., Professor (1971); B.A., Stanford Univ., 1941; M.S., Univ. of California at Los Angeles, 1942.

ROBERT MAURICE BERG, Major, U. S. Air Force; Assistant Professor (1971); B.S., South Dakota State Univ., 1958; M.B.A., Ohio State Univ., 1967; Ph.D., (pending).

SHERMAN WESLEY BLANDIN, JR., Associate Professor (1968); B.S., Naval Academy, 1944; B.S., Georgia Institute of Technology, 1952; M.S., 1953.

RORERT EDWARD BOYNTON, Associate Professor (1970); B.A., Univ. of Minnesota, 1956; M.A., 1962; Ph.D., Stanford Univ., 1968.

JAMES FREDERICK CALLAHAN, Lieutenant Commander, U.S. Navy, Assistant Professor (1970); B.S., Univ. of Pennsylvania, 1960; M.S., Naval Postgraduate School, 1970.

WILLIAM AYERS CAMPBELL, Assistant Professor (1970); B.S., Tuskegee Institute College, 1937; M.S.I.M., Univ. of Pittsburg Graduate School, 1949.

FRANK ELMER CHILDS, Professor (1965); B.A., Williamette Univ., 1934; M.B.A., Univ. of Southern California, 1936; Ph.D., Univ. of Minnesota, 1956.

EDWIN JOHN DORAN, Lieutenant Colonel, U. S. Marine Corps; Assistant Professor (1969); B.A., Univ. of Pennsylvania, 1955; M.S., Naval Postgraduate School, 1968.

EDWARD JOSEPH FREED, Assistant Professor (1972); B.S. Moston College, 1966; M.B.A., Wharton School of Finance and Commerce, Univ. of Pennsylvania, 1968.

WILLIAM ALAN MAUER, Associate Professor (1966); A.B., San Jose State College, 1955; M.S., Agricultural and Mechanical College of Texas, 1957; Ph.D., Duke Univ., 1960.

NORMAN PLOTKIN, Assistant Professor (1969); B.S., Univ. of California Los Angeles, 1948; B.F.S., Georgetown Univ., 1950; M.S., Claremont Graduate School, 1966; Ph.D., 1969.

HERBERT CHARLES PUSCHECK, Major, U. S. Army, Assistant Professor (1970); B.S., West Point, 1958; M.S., Purdue Univ., 1964; Ph.D. 1969.

RICHARD EDWARD SAUNDERS, Commander, U. S. Navy, Assistant Professor (1971); B.S., Naval Postgraduate School, 1967; M.S., 1970.

RONALD LAGE SEGERBLOM, Lieutenant Commander, U. S. Navy, Assistant Professor (1972); B.A., Univ. of Washington, 1961; M.S., Naval Postgraduate School, 1970.

GEORGE LAWRENCE STANSBURY, Commander, U. S. Navy, Assistant Profesosr (1972); B.S., Florida Southern College, 1951; M.S., Naval Postgraduate School, 1963.

ROBERT VON PAGENHARDT, Professor (1967); A.B., Stanford Univ., 1948; M.S., 1954; Ph.D., 1970.

CARLTON LEROY WOOD, Professor (1966); B.A. Univ. of Washington, 1932; M.A., Columbia Univ., 1944; Ph.D., Heidelberg Univ., 1936.

* *The year of joining the Postgraduate Faculty is indicated in parentheses.*

The Navy Management Systems Center was established as a separate Naval Activity in February 1966 for the purpose of fulfilling Department of Defense requirements for educating high level military and civilian personnel working in planning, programming, budgeting, systems analysis or resource management activities of Departmental or Agency Headquarters, and selected major commands. Quotas to the Defense Management Systems Course are controlled by the sponsoring agency; i.e., the Departments of Army, Navy, Air Force, and the Office of the Secretary of Defense.

In addition, the Navy Management Systems Center conducts a four-week Management Course for Commanding Officers, Executive Officers and others directly concerned with Navy shore station management. The purpose of this course is to provide those responsible for managing shore station complexes the most modern management concepts in such areas as facility management, resource management systems, systems and operations analysis, organization and personnel management, and public affairs. Quotas to the Navy Shore Station Management Systems Course are controlled by the Chief of Naval Operations, OP 993C4.

The Center has also conducted short courses for allied governments in their countries and in Monterey.

Since 1966, the Center has graduated nearly 4,500 students.

Faculty members of the Center are a part of the regular faculty of the Postgraduate School.

DEFENSE MANAGEMENT SYSTEMS COURSE

The Planning-Programming-Budgeting System developed since 1961 by the Office of the Secretary of

Defense has provided a framework for examining various force mixes, allocation of resources, and relationships to military capabilities.

The objective of the Defense Management Course is to provide an appreciation of the concepts, principles, and methods of defense management as they concern planning, programming, budgeting, and related activities. The course covers force planning, Department of Defense programming, program budgeting, and their interrelationships with resource management systems. Emphasis is placed on the analytical aspects of management, including requirements studies, systems analysis cost/effectiveness, cost estimating and analysis.

Students are not expected to become experts or technicians in the various disciplines and subjects included in the curriculum. The objectives are to provide orientation on the overall functioning of the defense management process, insights as to what defense management requires in the way of inputs and analyses for decisionmaking, understanding of the principles, methods and techniques used, and awareness of the interfaces between management requirements of the Department of Defense components and the Office of the Secretary of Defense.

The objective of the Navy Shore Station Management Systems Course is to provide Navy Commanding Officers, Executive Officers, and senior staff assistants an understanding of the most modern management concepts, procedures, and techniques as applied in the shore station environment. The relationship to the Defense Planning-Programming-Budgeting System and higher level objectives are stressed in order to focus attention on the necessary transition in out-look from command afloat to management ashore. The course covers organization and mission accomplishment, resources management, Navy budgeting and financial management, information and control systems, facilities management, behavioral science, and public affairs. Throughout the course emphasis is placed on the application of economic analyses and quantitative methods to improve the overall management of Navy shore stations.

SCHEDULE FOR FY 73

73-1	13 July-20 July 72	OSD Symposium
73-2	17 July-21 July 72	NMSC (1 wk.)
73-3	24 July-18 August 72	DMSC (4 wk.)
73-4	7 August-18 August 72	NMSC (2 wk.)
73-5	21 August-15 Sept. 72	DMSC (2 wk.)
73-6	4 Sept.-15 Sept. 72	NMSC (2 wk.)
73-7	18 Sept.-13 October 72	DMSC (4 wk.)
73-8	2 October-6 October 72	NMSC (1 wk.)
73-9	16 October-10 Nov. 72	DMSC (4 wk.)
73-10	30 October-10 Nov. 72	NMSC (2 wk.)
73-11	13 Nov.-17 Nov. 72	NMSC (1 wk.)
73-12	29 Nov.-7 Dec. 72	F/G (1 wk.)
73-13	11 Dec.-15 Dec. 72	DMSC Seminar
73-14	8 Jan.-6 April 73	IDMC (13 wk.)
73-15	8 Jan.-2 Feb. 73	DMSC (4 wk.)
73-16	5 Feb.-2 March 73	DMSC (4 wk.)
73-17	5 March-30 March 73	DMSC (4 wk.)
73-19	30 April-25 May 73	DMSC (4 wk.)
73-20	4 June-29 June 73	SIDMC (4 wk.)

A similar schedule is planned for FY 74.

Students from the Navy Management Systems Center with Spanagel Hall in the background

POSTGRADUATE SCHOOL STATISTICS
GRADUATES BY YEARS

	1946-1950	1951-1955	1956-1960	1961-1965	1966-1970	1971	Total
Bachelor of Arts	.....	.....	.....	180	389	78	647
B. S. in Aeronautical Engineering	73	212	212	181	61	12	751
B. S. in Chemistry	.....	.....	3	3	4	4	14
B. S. in Communications Engineering	.....	.....	42	95	45	.....	182
B. S. in Electrical Engineering	62	115	98	253	182	33	743
B. S. in Engineering Electronics	94	177	92	172	81	.....	616
B. S. in Engineering Science	.....	.....	.....	.....	141	41	182
B. S. in Environmental Science	.....	.....	.....	12	.....	.....	12
B. S. in Management	.....	.....	.....	53	1	.....	54
B. S. in Mechanical Engineering	43	116	52	82	53	4	350
B. S. in Meteorology	16	104	77	108	49	13	367
B. S. in Operations Research	.....	.....	.....	.....	49	26	75
B. S. in Physics	.....	15	36	75	35	8	169
Bachelor of Science	.....	56	94	583	259	39	1,031
Total Baccalaureate Degrees	288	795	706	1,797	1,349	258	5,193
M. S. in Aeroelectronics	.....	.....	.....	4	3	.....	7
M. S. in Aeronautical Engineering	.....	.....	.....	36	112	33	181
M. S. in Chemistry	.....	.....	16	5	32	5	58
M. S. in Communications Engineering	.....	.....	.....	.....	11	.....	11
M. S. in Computer Science	.....	.....	.....	.....	34	32	66
M. S. in Computer Systems Management	.....	.....	.....	.....	181	92	273
M. S. in Electrical Engineering	7	34	46	86	267	53	493
M. S. in Engineering Acoustics	.....	.....	.....	.....	13	9	22
M. S. in Engineering Electronics	68	120	78	104	40	.....	410
M. S. in Management	.....	.....	.....	406	633	230	1,269
M. S. in Management/Data Processing	.....	.....	.....	22	66	.....	88
M. S. in Material Science	.....	.....	.....	5	9	.....	14
M. S. in Mechanical Engineering	20	36	48	49	99	24	276
M. S. in Meteorology	23	19	40	53	53	16	204
M. S. in Oceanography	.....	.....	.....	.....	119	51	170
M. S. in Operations Research	.....	.....	.....	63	305	120	488
M. S. in Physics	.....	25	104	135	124	23	411
Master of Science	.....	17	65	102	56	6	246
Total Master's Degrees	118	251	397	1,070	2,157	694	4,687
Aeronautical Engineer	.....	.....	.....	4	33	3	40
Electrical Engineer	.....	.....	.....	.....	40	12	52
Mechanical Engineer	.....	.....	.....	.....	6	3	9
Doctor of Philosophy	.....	.....	1	14	25	2	42
Total Degrees	406	1,046	1,104	2,885	3,610	972	10,023

GRADUATES OF THE NAVAL POSTGRADUATE SCHOOL 1970

DIPLOMAS OF COMPLETION

AERONAUTICAL ENGINEERING

SLONECKER, Michael L., LTJG, USN

COMPUTER SYSTEMS MANAGEMENT

JOHNSON, Thomas P., LTJG, USN
KAFKA, William F., LT, USN
NORWOOD, Kenneth E., LT, USN
PFEIFFER, John J., LCDR, USN

ELECTRICAL ENGINEERING

HERDER, William R., CPT, USMC
HILL, Richard D., LT, USN
ROBERTS, Ernest P., LCDR, USN
WHITE, Stephen D., LT, USNR

ENGINEERING SCIENCE

ARUNDALE, Samuel H., LT, USNR
KECK, Leland S. Jr., LT, USN

MANAGEMENT

BARSTAD, Clarence H., LCDR, USN
HATCHER, Jerry M., LCDR, USN
KIM, In Muk, CDR, Republic of Korea Navy
McCARTHY, Peter R., MAJ, USMC
McCORMICK, James G., LTC, USMC
McNAIR, Morris L. Jr., LCDR, USN
MORGAN, James E., CDR, USN
O'DER, John T., CDR, USN
RASMUSSEN, Larry K., LCDR, USN
WOLYNIES, Jon G., LCDR, USN

METEOROLOGY

KATONA, John B., LT, USN

OCEANOGRAPHY

BEALLE, William E., LCDR, USN
CHANDLER, James F., LT, USN
HERMANN, Kermyn J., LT, USN

OPERATIONS RESEARCH

ENGLER, Brian D., LTJG, USN

STAFF COMMUNICATIONS

GILLETT, Robert M. Jr., LCDR, USN
HURLBUT, Bonny A., LT, USN
POPE, William H., LCDR, USN

ACADEMIC DEGREES

BACHELOR OF ARTS

ALBERTS, Richard P., CDR, USN
ALBRIGHT, Robert E., LCDR, USN
AMUNDSEN, Rickard O. Jr., LCDR, USN
BACA, Fidel L., LT, USN
BAIRD, Don W., LCDR, USN
BARRISH, Paul D., CDR, USN
BENNETT, David G., LCDR, USN
BLACKWELL, Jack L., CDR, USN
BLOOM, Donald D., CDR, USN
BOATRIGHT, Keith A., LCDR, USN
BOYLE, Ronald R., LCDR, USN
BRIGGS, Stanley, LCDR, USN
BRUGMAN, Thomas C., LCDR, USN
BUCKLEY, John E., CDR, USN
CALLOWAY, Charles L., LT, USN
CATER, Michael C., LCDR, USN
CLARK, Charles F. Jr., CDR, USN
COLLIER, Lacey A., LCDR, USN
COLLIS, Charles D., LCDR, USN
COOK, Oren F., LT, USN
CORNELL, Gordon C., CDR, USN
COTTER, Joseph D. Jr., LT, USNR
CRAMER, Dean E., CDR, USN
DAVIS, Grady W. Jr., LCDR, USN
DAVIS, John D., LCDR, USN
DOROW, William R., CDR, USN
DOYLE, John F., LCDR, USN
FARON, John F., CDR, USN
FINDLEY, Ronald C., LCDR, USN
FINK, Jerome I., CDR, USN
FITZPATRICK, Thomas J., LCDR, USN
GERWE, Franklin H. Jr., LT, USN
GLICKMAN, Thomas W., LCDR, USN
GOMPPER, James H., LT, USN
GONZALEZ, Robert N., LCDR, USN
GOODLOE, Robert V. Jr., LT, USN
GORE, James R., CDR, USN
GREER, Robert E., LCDR, USN
HAMRICK, Franklin G., CDR, USN
HENDRICKSON, Claude F. Jr., CDR, USN
HERRING, Paul E., CDR, USN
HOKENESS, Sylvan P., LCDR, USN
HOOPER, Harold D., LCDR, USN
HUDSON, Lyndon R., LT, USN
JACKSON, Lester T., LCDR, USN
JONES, James V., LT, USN
JONES, Stanley W., LCDR, USN
JONES, William D., LT, USN
KUSHNER, David A., LCDR, USN
KVEDERIS, James P., LCDR, USN
LUEHRING, Davidson, LCDR, USN
MARTIN, Edward F. III, LCDR, USN
MATSON, Bruce W., CDR, USN
MERRILL, Hugh A., LCDR, USN
MORIN, Thomas E., LCDR, USN
MORRIS, John E., LCDR, USN
O'CONNELL, Daniel E., CDR, USN
OLWIN, James L., LT, USN
PAGANELLI, John E., CDR, USN
PARRIE, E. James, LT, USN
ROCKWELL, William A., CDR, USN
ROSE, Michael A., LCDR, USN
ROSEMAN, Troy B., CDR, USN
SAGEHORN, Robert W., LCDR, USN
SCHAFER, Alfred E., CDR, USN
SHATTUCK, George W., LCDR, USN
SHELDON, George E. Jr., CDR, USN
SHIRLEY, Fred E. Jr., LCDR, USN
SIMPSON, John E. II, LCDR, USN
SLEEMAN, Charles F., CDR, USN
SMITH, William P., LCDR, USN
SPITZ, Gerald A., LCDR, USN
STRONG, Henry H. Jr., CDR, USN
TURNER, Robert C., CDR, USN
VANDEWATER, George L. Jr., CDR, USN
WALTZER, Jacob, CDR, USN
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Provost Clauser (left) congratulates LCDR Richard W. Tripp, Jr., as he receives the degree of Doctor of Philosophy

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